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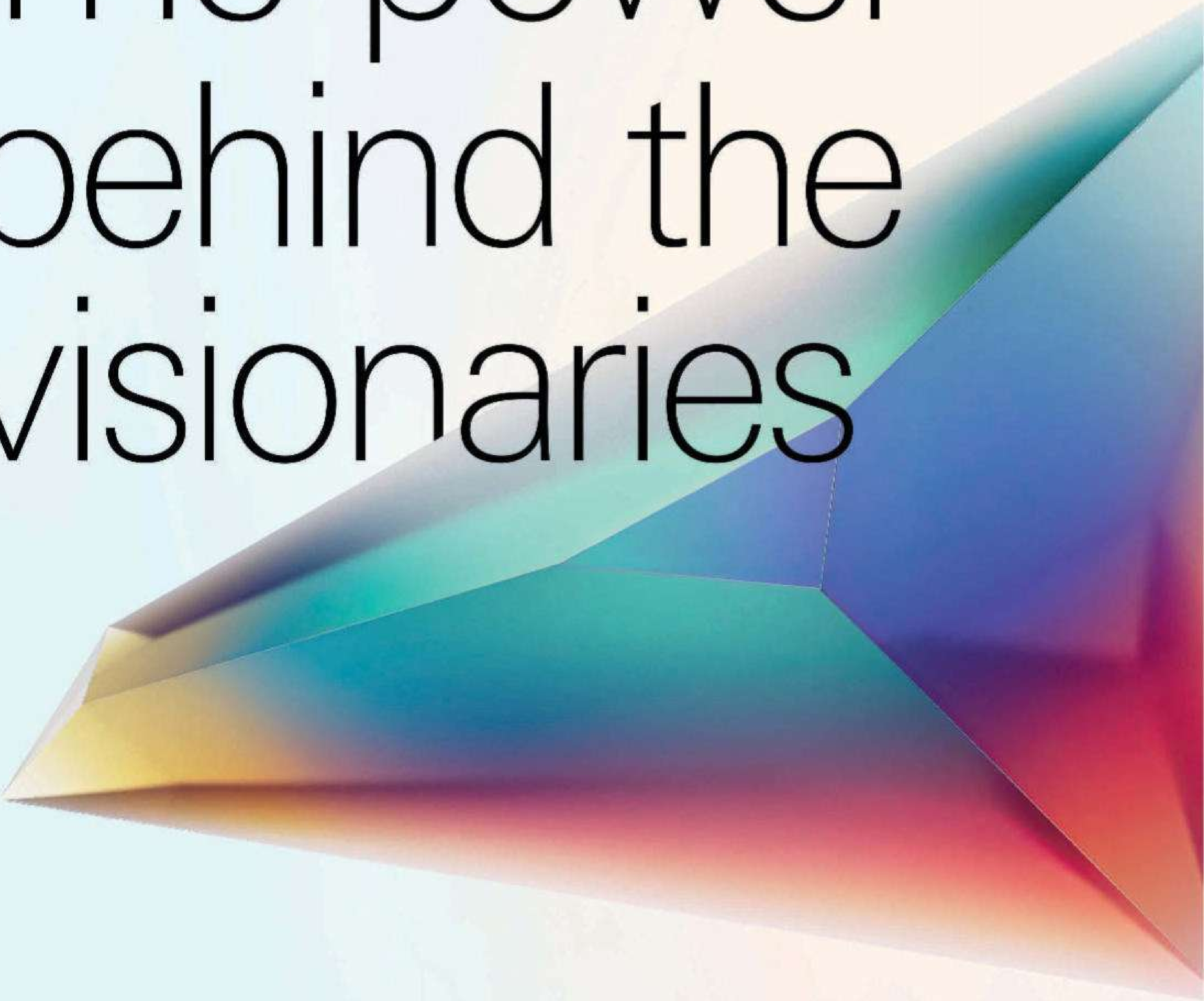

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Total solar eclipse 2024: Texas, US

Experience the magnificent solar eclipse that will take place across North and Central America next year. Join *New Scientist* features editor Abigail Beall on a visit to NASA's Space Center Houston and two observatories. Eclipse chaser John Mason then leads the main event at an exclusive ranch. This eight-day tour begins on 3 April and costs £4399.

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Instant Expert

Artificial intelligence

Following the release of ChatGPT, there has been an explosion of interest in generative AIs that create text or images. But how do these systems work? And what are the ethical, social and political challenges raised? Join our expert speakers in London on 25 November to hear about advances in natural language processing, computer vision and AIs for the creative arts.

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Podcast

Weekly

This week, the team explore some newly observed extremes in outer space, from the biggest marsquakes to the oldest fast radio bursts some 8 billion years ago. They hear how reactions can be evoked in people who are sleeping. Plus, the world's tiniest particle accelerator and why some engineers think we can run huge, energy-guzzling data centres at much, much hotter temperatures.

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Sophia the robot Become an expert in the coming AI revolution

DARIN OSWALD/IDAHO STATESMAN VIA AP/ALAMY

Total eclipse Texas is the ideal spot to witness this solar spectacle

Video

Exoskeleton advances

People who use wheelchairs may one day be able to walk with the help of an exoskeleton made by Wandercraft. It is currently used inside hospitals to help people relearn to walk after a stroke. But new research is under way to create an exoskeleton that can be used anywhere and helps people with spinal cord injuries and motor neuron disease.

youtube.com/newscientist

Newsletter

Fix the Planet

Electrolysers that split water to produce hydrogen have trouble working with sea water, which is full of corrosive salt. Environment reporter James Dinneen looks at new electrolyser designs that overcome this. Attaching these to offshore wind turbines could make clean-burning hydrogen directly from the ocean.

newscientist.com/ fix-the-planet

Newsletter

> **"We need to avoid a competition between water for drinking and water for fuel production"**

Essential guide

Our lives are often governed by the familiar ticking of the clock, but where does this ticking come from? This *New Scientist Essential Guide* explores why time is the fundamental facet of our existence. Available to download in the *New Scientist* app or to purchase in print from our shop.

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The fossil fuel-free state

South Australia's push to net zero offers lessons – and hope – for the world

WE NEED to urgently slash global carbon emissions to avoid catastrophic climate change. The scale of the task can seem overwhelming. But there are grounds for optimism in places where action to ditch fossils fuels is accelerating, offering vital lessons for the rest of us.

One such place is the state of South Australia. In 2007, just 1 per cent of its electricity came from solar and wind. Today, this proportion has risen to almost 73 per cent – the highest of any major grid in the world. It is tipped to become the first large-scale grid to run solely on solar and wind, a goal it could reach in a few years.

How has it managed this remarkable transition? As we explore on page 36, it has taken a great deal of courage from South Australia's political leaders, who have been unusually willing to try cutting-edge technologies like grid-scale batteries and virtual power plants, as well as widespread buy-in from citizens, who have enthusiastically covered their homes in solar panels. The state has stuck doggedly to its vision while many detractors, including top figures in Australia's federal government, have fiercely criticised it for moving too fast.

> "Renewable energy comes in many forms. If there's a will to harness it, there's a way"

The long-term benefits to South Australia won't just be environmental – they will be economic too, because when it can produce all of its energy on its own, it will be liberated from international coal and gas price shocks.

The state has certain advantages: abundant sun, wind and space for building infrastructure. Plus, it has a population of only 1.8 million. But the beauty of renewable energy is that it comes in many forms – so if there's a will to harness it, there's a way.

Momentum is building. The International Energy Agency expects a record 440 gigawatts of renewable energy capacity to be added globally in 2023, and South Australia isn't the only trailblazer. With that in mind, this is the first in a series of stories in which we will report on similarly groundbreaking projects around the world that demonstrate how we can reach net zero before it is too late. ▮

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Events

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Artificial Intelligence and the next computing revolution

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Join our expert speakers on an engaging journey through Artificial Intelligence, its current power, its potential and its risks.

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- **The ethics of AI**
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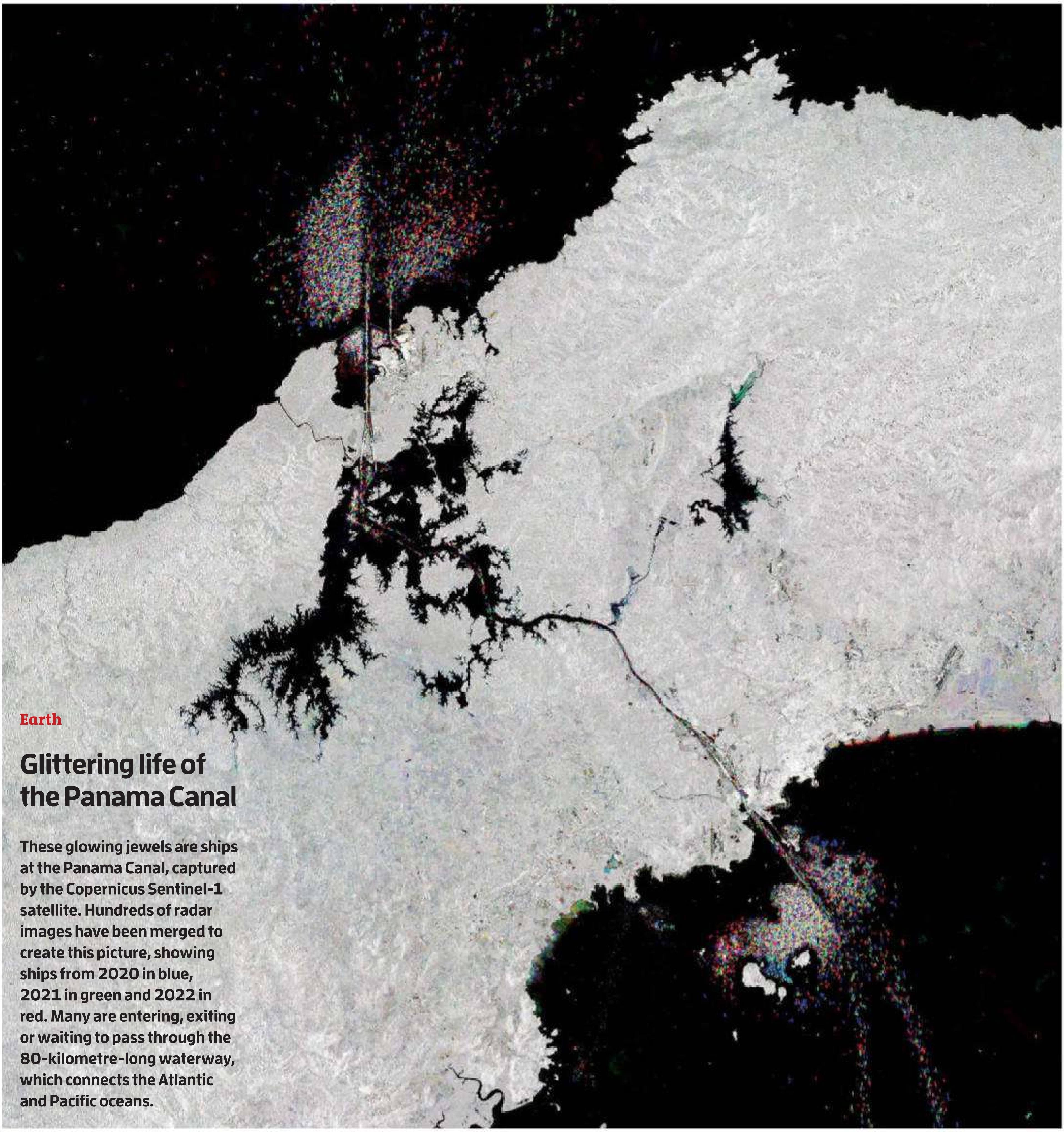
Strange explosion
Cosmic blast makes our understanding of space uncertain **p9**

Wildlife toll
The Amazon's pink dolphins are feeling the heat **p10**

Filtered out
HEPA air filters cut covid-19 sick days in schools **p13**

Bridging the gap
Chatbots could show us how to make social media less toxic **p15**

Night moves
People can respond to words they hear while asleep **p16**



Earth

Glittering life of the Panama Canal

These glowing jewels are ships at the Panama Canal, captured by the Copernicus Sentinel-1 satellite. Hundreds of radar images have been merged to create this picture, showing ships from 2020 in blue, 2021 in green and 2022 in red. Many are entering, exiting or waiting to pass through the the 80-kilometre-long waterway, which connects the Atlantic and Pacific oceans.

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Archaeology

Farming linked to disease spike

An analysis of DNA from human remains shows that more diseases jumped to people after we started domesticating other animals, finds **Michael Le Page**

LEFTERIS PITARAKIS/AP/ALAMY

The bones of a person buried in a "plague pit" in London in the 14th century

DNA from the bones and teeth of 1300 people who died up to 37,000 years ago has revealed what infectious diseases some of them had at death – as well as how the incidence of certain diseases changed over time. The findings show that diseases were much more likely to jump to humans from other animals after the advent of farming.

This is the first direct evidence that the domestication of animals led to humans acquiring more infectious diseases, according to Eske Willerslev at the University of Copenhagen in Denmark and his colleagues. This "profoundly impacted global human health and history throughout the millennia and continues today", Willerslev and his team write.

The study looked at a wide range of microbes in human remains from all over the world and many different times, making it the largest and most comprehensive of its kind. The oldest human remains were from around 37,000 years ago, but most were between several thousand and a few hundred years old.

The researchers exploited the fact that it is becoming common to sequence the genomes of ancient people, and that the DNA of bacteria or DNA viruses present in the bones or teeth gets sequenced, too. These microbial sequences are filtered out when ancient human genomes are reassembled. To identify them, the team analysed raw data from the sequencing of more than 1300 ancient human genomes, including 130 that haven't yet been published.

Most of the microbial DNA the researchers found was from soil bacteria, suggesting bacteria got into the bones after burial. In teeth, much of the microbial DNA came from bacteria known to live in people's mouths.

However, the team was also able to identify many disease-causing bacteria and viruses that were in the blood of people before they died and may have caused or contributed to their death.

The most common was the bacterium that causes the plague, *Yersinia pestis*, found in 39 people, or 3 per cent of the remains. This bacterium mainly infects rodents, but can be spread to people by fleas.

The oldest plague cases were in three people who lived in various parts of Asia around 5700 years ago. The bacterium was also found in a person entombed on Orkney in Scotland around 4800 years ago – about 800 years before the previous earliest known case of the plague in Britain.

37,000

Oldest human remains analysed were from this many years ago

1300

Number of ancient human genomes analysed

3%

Proportion of remains assessed that had plague bacteria

Overall, the team found lots of plague cases between 6000 and 3000 years ago. Then there was a gap until 2000 years ago, when there was a wave lasting for a few centuries, then another gap until a second wave corresponding with the medieval "Black Death" plague pandemic (bioRxiv, doi.org/k2pz).

The researchers think that the gaps where no plague cases were detected "represent an actual reduction in the underlying incidence of the disease". Their findings fit with other studies suggesting that the early form of plague wasn't very transmissible and died out, to be replaced by more transmissible strains that caused pandemics.

The next most common microbe was *Borrelia recurrentis*, which causes a disease spread by body lice called louse-borne relapsing fever. This disease is now rare, but the team found it in 31 people, 2.3 per cent of the total, suggesting it was widespread in the past.

The first cases the researchers found were in Scandinavia around 4500 years ago, implying *B. recurrentis* first jumped from animals into people around this time, but it isn't clear what the original animal source was.

Other diseases identified include malaria, hepatitis B, leprosy and leptospirosis, also known as Weil's disease.

The researchers divided the kinds of microbes they found into five broad types, including zoonotic diseases, those that jumped from animals into humans. They found there was an increase in zoonotic diseases from about 6000 years ago, but not of any of the other four types.

"The risk and extent of zoonotic pathogen transmission likely increased with the adoption of more widespread husbandry practices and pastoralism," the study says.

Pontus Skoglund at the Francis Crick Institute in London says the work is "promising". While it is possible to identify trends in the incidence of pathogens in the past, studies like this need to take account of potential biases, he says. For instance, people who died of disease may have been buried in different ways to the standard, or cremated instead.

Another issue is that standard DNA sequencing misses RNA viruses, such as flu and coronaviruses, which may have caused major outbreaks in the past. Specific techniques are needed to detect these viruses.

Willerslev declined to discuss the findings before publication in a peer-reviewed journal. ▮

Zoology

Why birds' eyes can be blue, green, pink or orange

Sofia Quaglia

BIRDS often have vibrant plumage, but the dazzling diversity in their eye colour also seems to be important for their success.

Many birds have brightly coloured eyes. The black-and-red-broadbill (*Cymbirhynchus macrorhynchos*), for instance, has sapphire blue or vivid emerald eyes. Some species of green pigeon (in the genus *Treron*) have magenta eyes and the bank cormorant (*Phalacrocorax neglectus*) sports a "sunset" iris, where the top half of its eye is orange and the bottom half is teal.

To investigate why this happens, Eamon C. Corbett at Louisiana State University and his colleagues analysed more than 250 previously published studies. One idea was that eye colour aids vision and so boosts birds' ability to find food. But the new review suggests evidence for this hypothesis is lacking.

Instead, the studies generally point towards another factor. "I think the strongest driver of eye colour variation in birds is signalling," says Corbett. In other words, birds use eye colour to communicate (*International Journal of Avian Science*, doi.org/k2pv).

For instance, some of the studies Corbett's team analysed demonstrated that male Queen Carola's six-wired birds-of-paradise (*Parotia carolae*) use their yellow irises to attract mates. And a study in yellow-eyed penguins suggested that birds with brighter yellow eyes had more breeding success.

Communication can also be about intimidation. For instance, a study of jackdaws revealed that the birds were more hesitant to approach a nest containing an image of a jackdaw with bright eyes, but they weren't deterred by an image of a jackdaw with darker eyes.

There may be even more factors behind variation in bird eye colour, says Juan José Negro at the Spanish National Research Council. ▮

Space

Odd cosmic explosion may break our understanding of space

Alex Wilkins

THE unexpectedly powerful light from the brightest space explosion ever seen may mean that space is more transparent than we thought.

Last year, astronomers witnessed a flash of gamma rays that was brighter than anything they had previously measured. By comparing it with other gamma ray bursts, researchers estimated that such a bright event would happen only once every 10,000 years.

This flash, called GRB221009A, was made of up of photons (or light particles), some of which were so energetic they couldn't be detected by Earth-based telescopes.

Now, Cao Zhen at the Chinese Academy of Sciences in Beijing and his colleagues have detected extremely energetic photons from GRB221009A indirectly, by looking for showers of particles produced when such photons hit Earth's atmosphere (arXiv, doi.org/k2px).

Gamma ray photons are unique in that they can be reflected by other photons. Because of this, the photons observed by the researchers should have been reflected by light that fills the universe from star formation – called extragalactic background light – long before they reached Earth.

"It could mean the universe is more transparent than we thought"

"If I take the James Webb Space Telescope, I can look back and see optical and infrared photons all the way back to the very early universe, but I can't see the very high-energy photons that far because those photons themselves scatter off other photons," says Andrew Levan at Radboud University in the Netherlands. "It's like looking through a mist."

There is a chance that the showers of particles the astronomers detected aren't actually caused by photons, but by different particles like energetic muons, says Levan. Or the photons might not be as high energy as they appear, because detecting these particles through atmospheric showers is difficult.

If the photons really are as energetic as they seem to be, it would mean the universe is more transparent than we thought, with less extragalactic light.

Another explanation could require new physics. For example, the photons could have been converted into a different type of particle that doesn't interact with extragalactic light for their journey across space.

That might be a hypothetical ultralight particle called an axion, which could explain a swathe of mysteries such as dark matter or symmetry violations in particle physics.

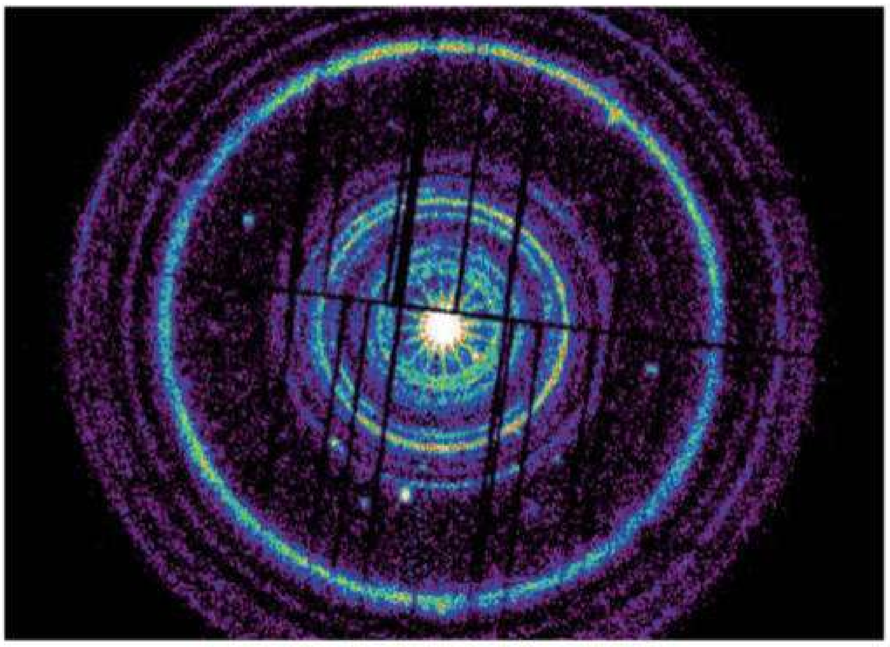
This axion would interact with the magnetic field of a galaxy, such as the Milky Way, and convert back into a photon once it reaches that galaxy.

"It has the same net observational effect – it makes the universe more transparent," says Andrew Mummery at the University of Oxford. "You can have as much extragalactic background light as you want, effectively, if you've got an axion travelling through it rather than a high-energy photon."

The astronomers who made the measurements estimate there is roughly a 5 per cent chance the photons were actually something else, such as cosmic rays, so we will need many more measurements of high-energy photons before new physics can be invoked, says Mummery.

Unfortunately, that requires a certain degree of luck, because events that produce photons with energies this high are exceedingly rare, he says. ▮

The gamma ray burst known as GRB221009A surrounded by dust rings



ESA/XMM-NEWTON/M. RIGOSELLI (INAF)

Field notes Puerto Nariño, Colombia

Amazon's pink dolphins are feeling the heat

Months of extreme temperatures and low rainfall are taking a toll on wildlife and people in the rainforest, finds **Luke Taylor**

EVEN in the dry season, the Amazon river is so vast that I can't make out the other side with my binoculars. We have travelled 2 hours downriver from the Colombian town of Puerto Nariño, searching for a dead dolphin reported by a fisherman. We only spot the carcass on the riverbank thanks to the vultures perched on top.

The pink river dolphin (*Inia geoffrensis*) is symbolic of the biodiversity of the Amazon rainforest and is sacred to many Indigenous communities, yet its numbers are declining by around 5.5 per cent each year, raising fears it could eventually disappear.

Jimena Valderrama, a vet working with the Omacha Foundation, inspects the 2.5-metre-long carcass (pictured) to learn what killed it, but there is no immediately obvious cause. "When a species is endangered, the loss of every individual is incredibly important for their survival, which is why we fight so hard to save each one," she says.

The dolphins face many threats. The fish populations they feed on are dwindling, an illegal mining boom is poisoning the food chain with mercury and fishers kill them for their meat, which is used as bait for catching piracatinga, a kind of catfish.

On top of all that, the Amazon is currently experiencing its most intense dry season in more than a decade. Last week, the Amazon's second largest tributary, the Rio Negro in Brazil, reached its lowest recorded level since 1902. There are growing signs that the extreme temperatures are killing off local wildlife, and this could be a glimpse of what is to come from climate change.

The dolphin carcass we found on the Colombian-Peruvian border follows reports of large numbers of dead fish in the surrounding rivers and lakes. Even more concerningly, 153 dolphins have been found washed up in Brazil's Lake Tefé since late September.

Extremely low river levels exacerbated already high temperatures and were a direct cause of the die-off, say local researchers. Water temperature readings at Lake Tefé exceeded 39°C (102°F), which is 9°C (16°F) above average for this time of year.

5.5%

Annual decline in the population of pink river dolphins

The Omacha team in Colombia usually finds one dead dolphin a year, but they have already found two this month, says Valderrama. Both probably died after getting entangled in fishing nets.

As climate change intensifies, these incidents will become more common, she says. "Generally, when the rivers are low, there are more nets set in a smaller amount of water, leading to more dolphin mortality." Declining fish stocks could also increase conflict with fishers, who occasionally kill dolphins for stealing their catch.

Dolphins are an umbrella species, meaning their success influences the fate of many other species in the ecosystem, so it makes sense to focus conservation efforts on them, says Silvia Vejarano, a biologist and conservation specialist at WWF, which is supporting Omacha.

"The dolphins help make otherwise intangible problems, that are threats not only to dolphins but also the millions of people who inhabit the Amazon, visible," she says.

As we travel on the Loretoyacu river, a tributary of the Amazon, we must abandon the boat and walk along the banks because the water is too shallow after two months of unusually low rainfall.

For us, it is an inconvenience and we get caught in a tropical downpour. But for many who inhabit the Amazon rainforest, it is a serious threat. In recent months, people have been cut off from food supplies, fuel and hospitals. In Brazil, the government is distributing aid by helicopter to some Indigenous communities.

"The drought has been really worrying as we rely on rainwater to drink," says Gentil Gomez, a community leader for the Ticuna Indigenous community, who live off the fish in Lake Tarapoto, Colombia. "It's also hard to get to Puerto Nariño to buy supplies, and we've seen different species of fish die in our rivers."

A recent shift from the La Niña weather phenomenon to El Niño is playing a role in the abnormal weather. But a study by World Weather Attribution concluded that without the impact of humans, the recent record temperatures across South America would be more than 100 times less likely.

Precisely how climate change is affecting wildlife across the huge range of the Amazon rainforest is poorly understood, says Vejarano. "We do not really know yet all the consequences that warming temperatures have for all of the fauna, microorganisms and plankton that regulate the ecosystem, but we are increasingly seeing the consequences in the dolphins. And they are just the tip of the iceberg." ▮

UPPER: WWF; LOWER: LUKE TAYLOR

A tributary of the Amazon has become impassable after unusually low rainfall (above); conservationists recover the body of a pink river dolphin for analysis (left)

Physics

Mysterious rotation trick makes magnets float in the air

Karmela Padavic-Callaghan

THERE is a simple way to levitate magnets – and physicists are now beginning to understand how it works. The technique could have applications for robotics in the future.

In 2021, Hamdi Ucar – then at Göksal Aeronautics in Turkey – posted a YouTube video showing two magnetic spheres levitating on either side of a rapidly spinning bar magnet that was positioned with its north-south poles oriented vertically.

Ucar also published a paper on the phenomenon, which attracted the attention of Rasmus Bjørk at the Technical University of Denmark.

With a colleague, Bjørk decided to replicate Ucar's levitation technique. "We sat down for half an hour and tried. I was like, it's completely out of the question, it simply shouldn't work. And then it just worked. We were completely baffled by this," he says.

J. M. HERMANSEN ET AL.

A demonstration of a spinning magnet being used to keep another one afloat

Now, Bjørk and several other colleagues, all at the Technical University of Denmark, think they have figured out what is going on to make the magnet levitate.

They started with Ucar's set-up, where a "floater" magnet levitates when placed on top of another magnet that is spinning hundreds of times every second.

Then, Bjørk and his colleagues tested a range of spinning frequencies and floater sizes while filming the magnets and measuring their magnetic fields. The researchers also developed a computer simulation of the experiment (*Physical Review Applied*, doi.org/k2pq).

Team member Frederik Durhuus says the rotation is key to the process.

Many people are familiar with the way two magnets repel one another when their respective north poles or south poles are close together. But one of the magnets will usually flip over, meaning that a north and south pole are close together – at which point they stick to each other.

Durhuus says the rotation counters this magnetic "flipping" and keeps the floating magnet levitating. He compares it to the way that a spinning top counters the downward pull of gravity and spins for longer than we might expect it to.

Ucar's experiments show that the effect can persist even when the rotating magnet is oriented horizontally, rather than vertically like a spinning top. He disagrees with some details of the team's numerical and theoretical models, but says that their independent validation of this surprising effect is important.

"I don't think we will be able to make any [magnetically levitating] trains with this any time soon, but it will be interesting to see where it can be useful because it does not require very fancy equipment," says team member Joachim Hermansen.

Marcel Shuck at No-Touch Robotics in Switzerland says magnets are already used to suspend and transport objects in some industries. Using rotation to levitate magnets could be a simpler alternative to systems that require their magnets to be constantly readjusted, he says. ▮

Space

The moon is 40 million years older than we thought

A REANALYSIS of lunar rock has pushed back the age of the moon by 40 million years. This means it formed at least 4.46 billion years ago.

Scientists think the moon came into existence after a Mars-sized planet smashed into Earth and launched a ball of molten rock into space. As the magma surface of this object cooled and solidified, silicon crystals called zircons were formed. Because of their resilience to heat and harsh environments, the crystals have survived and can be used to identify the moon's earliest moments.

Zircon crystals contain radioactive uranium, which decays into lead at a well-defined rate, so scientists can determine a rock sample's age by measuring the amount of lead and uranium in it.

Philipp Heck at the University of Chicago and his colleagues have now reanalysed a sample of zircons from lunar rock brought back from NASA's Apollo 17 mission in 1972, using a technique called atom probe tomography, and found that the zircons are 4.46 billion years old (*Geochemical Perspectives Letters*, doi.org/gswzh7).

"We now have a date of the zircons, so we can tell the time by which the magma ocean must have been solidified, or largely solidified," says Heck. "It essentially anchors the entire lunar chronology. It's almost like putting a nail into the lunar timeline."

The particular zircon sample that Heck and his team looked at had been analysed in 2021 using a kind of mass spectrometry that suggested the sample was old, but the technique couldn't pinpoint whether the lead was from radioactive decay or was just there by chance.

Atom probe tomography, however, could analyse the make-up and position of the atoms in high detail, which helped show that they really were from radioactive decay. It uses a beam of charged particles to shave off an extremely thin section from a sample, of just a few atoms, and then a powerful laser evaporates these atoms into a mass spectrometer.

"It essentially anchors the entire lunar chronology. It's almost like putting a nail into the lunar timeline"

We know that the solar system formed about 4.57 billion years ago, which means we can constrain the moon's formation reasonably precisely, says Mahesh Anand at the Open University, UK.

"Previous studies have shown that the particular impact that formed the moon happened 50 million years after the formation of the solar system, so if we use that study, and this work, it is giving us a very narrow time window of only 50 million years within which the moon formed and solidified very, very quickly," says Anand. ▮

Alex Wilkins

Agriculture

Farming may expand to wilderness

As the world warms, vast wild areas in the north will become more suitable for farming

James Dinneen

CLIMATE change is expanding the amount of land suitable for farming in colder regions. While farming such areas could offset declines in crop yields elsewhere, it would also pose a threat to wild places once protected from cultivation by the cold.

As the planet warms, farmers will probably have to adapt to produce enough crops to feed a growing global population. "I would say that's inevitable," says Alexandra Gardner at the University of Exeter in the UK.

Gardner and her colleagues have now modelled how climate change under different emissions scenarios would alter the viable growing areas for more than 1700 kinds of crop, including potatoes, wheat and cotton. They then looked at where the newly suitable agricultural regions overlapped with "wilderness", defined as large spaces free from human pressures.

They found that under a moderate emissions scenario, 1.85 million square kilometres of wilderness became newly suited for at least one crop by mid-century. Under a very high emissions scenario, 2.75 million square kilometres of wilderness became farmable, amounting to 7 per cent of all the wilderness outside Antarctica.

This overlap disproportionately occurred in the northern hemisphere, both because of the large amount of wilderness there as well as the more rapid warming in higher latitudes. Some of the largest overlaps occurred in Russia, Canada and Alaska (*Current Biology*, doi.org/k2mw).

MICHAEL INTERISANO/AGSTOCK - RF/ALAMY

Farmland in Canada – soon, farmers may be expanding further north

Gardner says the models don't account for other factors that would affect whether crops could be grown in these areas, such as soil quality or proximity to transport networks.

But researchers say the pattern of overlap suggests a clear problem. "This is a real threat that vast areas in northern latitudes – very important for biodiversity, carbon balance, hydrological cycle, etc. – will be under pressure for food production," says Matti Kummu at Aalto University in Finland.

Climate-related declines in areas currently used for farming nearer the equator could exacerbate this pressure. Under both emissions scenarios, the researchers found that about 6 per cent of the land currently suitable for farming will become unfit for any crop by the middle of the century, and half of all land will see declines in the diversity of edible plants that would be able to grow there.

The problem could be alleviated by farming different crops, planting at different times, employing more irrigation and fertiliser or using current agricultural land more efficiently – for instance, by using less of it to raise livestock. Reducing emissions to mitigate climate change would also help.

Elisabeth Moyer at the University of Chicago says adaptations on existing farmland probably won't be enough to meet demand for food. "Unless the seed breeders save us, we're going to have to let things move around." ▮

Environment

Fermenting vegan cheese could make it more like dairy

THE ancient process of fermentation could give us plant-based cheese that has textures and flavours closer to those of traditional cheeses.

Plant-based alternatives to animal-derived food are increasingly popular, in part because of the environmental impact of livestock farming, but vegan cheeses have struggled to gain popularity with consumers.

Plant proteins behave differently to animal proteins, making it hard to replicate the texture and flavour of dairy cheese. This is partly why most vegan cheeses are derived from starch and coconut oil and contain little protein.

Carmen Masiá at the University of Copenhagen, Denmark, and her colleagues have now studied whether microbial fermentation – involved in the production of most dairy cheeses – could lead to better results. They used yellow peas, which have a high protein content and are sustainable to grow.

The researchers started with a "milk" made from yellow peas, sunflower oil, sugar and water. They inoculated this mixture with 24 different combinations of bacteria, mainly consisting of species that produce lactic acid, which are commonly used to produce many fermented foods, including yogurt, sourdough bread and kimchi.

Within 8 hours, all of the bacterial cultures created a firm texture similar to a soft cheese. They all, to varying extents, produced aroma compounds that usually contribute to the flavour of dairy cheeses, and some cultures removed more of the compounds responsible for bean-like flavours (*Future Foods*, doi.org/k2mt).

"It is important that vegan cheeses taste good and function like real cheese"

The results are encouraging, but more research is needed to make plant-based cheeses attractive to consumers. "It is important that they taste good, function like real cheese and, most importantly, that they have nutritional profiles similar to or better than real cheese," says Julian McClements at the University of Massachusetts Amherst. ▮

Gennaro Tomma

Technology

Brain-inspired chip could be the fastest at running AI

Jeremy Hsu

A COMPUTER chip inspired by the human brain can run artificial intelligence image-recognition operations 22 times as fast as comparable commercial chips. It also does it with 25 times better energy efficiency.

Dharmendra Modha at IBM Research and his colleagues designed the NorthPole chip as an array of intertwined computing cores and memory blocks. This allows it to bypass the von Neumann bottleneck, which describes how computers slow down while waiting on information exchanges between separated computing and memory units. The melding of computation and memory was inspired by how the human brain works. "It's a new way to look at computer architecture," says Modha.

The chip's digital architecture is also innovative in allowing each computing core to access distant memory blocks as easily as neighbouring ones, write Subramanian Iyer and Vwani Roychowdhury at the University of California, Los Angeles, in a commentary article in *Science*.

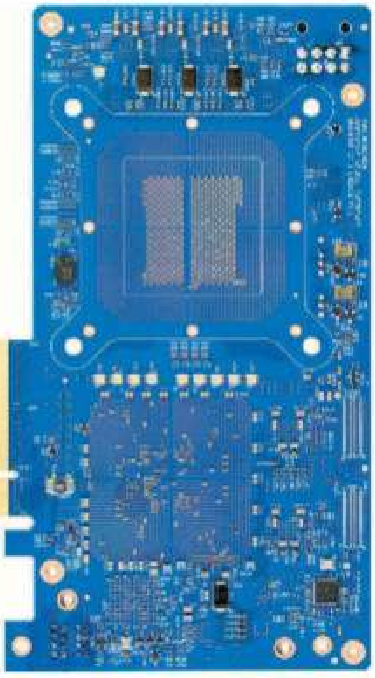
The IBM researchers have demonstrated how the new chip can run a common image-recognition AI 22 times as fast as any commercial chip on the market, and more efficiently, beating even the latest chips from NVIDIA, the leading manufacturer of those used for AI. They also showed that NorthPole can economically run AIs for speech recognition and natural language processing (*Science*, doi.org/gswnqq).

NorthPole also delivers better performance per transistor – the tiny electronic switches at the heart of computing technology – than other chip architectures.

However, NorthPole's design, which is specialised for running already trained AI models, means it can't perform other tasks, such as actually training an AI, or running larger AI models that require more memory than is available on the chip. But Modha's team plans to show how multiple NorthPole chips could support the large language models behind new chatbots such as ChatGPT.

The NorthPole chip would be even more useful if the researchers developed it so it allowed AIs to keep learning by simultaneously training and performing tasks, says Hava Siegelmann at the University of Massachusetts Amherst. "Their contribution to AI may be everlasting if they included such lifelong adaptation," she says.

Digital architecture redesigns like the NorthPole chip may help AIs to run efficiently in self-driving vehicles and aircraft, write Iyer and Roychowdhury. ▮



2023 IBM CORP

The NorthPole chip keeps its computing cores close to its memory blocks

Health

Air filters cut covid-19 sick days in schools

Clare Wilson

MATTHEW HORWOOD/GETTY IMAGES

AIR-FILTER machines put in a handful of UK schools reduced the number of covid-19-related sick days by more than 20 per cent, according to a small trial.

The trial involved putting HEPA filters, devices about the size of a tall kitchen waste bin, in classrooms in the Bradford area.

"You could still have outbreaks even if you have HEPA filters in your classrooms, but the underlying illness absence was over 20 per cent reduced when you have got the air cleaners in place," said Catherine Noakes at the University of Leeds, UK, at the World Health Organization Europe Indoor Air Conference last month. The results haven't yet been peer-reviewed.

The trial ran between September 2021 and March 2022, during which time the UK had a large wave of covid-19 infections caused by the omicron variant of the coronavirus. Ten schools got HEPA filters, with two or three put into each classroom, depending on the room size. These were compared with another 20 schools – similar to the first 10 in terms of buildings, the students' ethnicities and their families' income levels – that didn't have the filters.

The 20 per cent fall was only in absences related to covid-19, but the machines probably also cut sickness due to flu and other pathogens that cause coughs and colds, says team member Mark Mon-Williams, also at the University of Leeds. "This should reduce school absences related to any airborne illness," he says.

Having air filters in schools could also make families less likely to keep children off school as a precaution during a surge of flu or covid-19, says Mon-Williams. "We need to demonstrate that schools are safe, healthy environments."

Funders would need to weigh up the cost and benefits of the machines, says Michael Absoud at King's College London. HEPA filters can cost several hundred pounds each. It might be better to spend the money on school nurses or support for children with special needs, he says. "There are a lot of other priorities."

Air filters can also be noisy and produce a cold draught, says Stephen Baker at the University of Cambridge, who helped run a trial of HEPA devices at Addenbrooke's Hospital in Cambridge, the results of which are still awaited.

Nevertheless, the result from the schools trial is excellent, says Baker. Ideally, we would add appropriate air filtration as we rebuild public places to make them safer long term, he says. ▮

Neuroscience

We forget details when our brain picks the wrong thing to remember

Moheb Costandi

HAVE you ever forgotten items when trying to recall a shopping list? Or dialled the wrong phone number when attempting to memorise one? The brain mechanisms that cause us to draw a blank in such situations have now been identified.

Our "working memory" retains small pieces of information that are readily accessible for planning, understanding and solving problems. But it is prone to "swap errors", when we mistakenly attribute a feature from one object to another. For example, if we are shown a red square and a blue circle, and are then asked what colour the circle was, we might say red.

To understand why we make such errors, Jeff Johnston at Columbia University in New York and his colleagues used electrodes to record the activity of neurons in the brains of two macaque monkeys. "Both monkeys and humans can hold a few items in working memory at a time, and just like monkeys, humans will make swap errors, where they mistakenly report the wrong item and will sometimes forget items and have to guess," says Johnston.

The monkeys were shown two differently coloured squares, one above the other, for half a second. After these had disappeared, a black spot appeared where one of the squares had been. The animals were trained to indicate which colour square the spot had appeared in place of and whether that square had been on the top or bottom spot by gazing at the matching colour and location on a rotatable wheel.

The second version of this task was the same, aside from the spot appearing before the coloured squares. These tests required the monkeys to hold two items in their working memory – the locations of the squares and their colours.

> **"Everyone assumed there were simpler explanations for why we recall the wrong thing"**

When doing this for about 3 hours over multiple sessions, the monkeys performed both tasks correctly between 60 and 82 per cent of the time, but occasionally made swap errors.

During the tasks, the researchers recorded the activity of small populations of brain cells across the monkeys' frontal, parietal and visual cortices, which are known to encode neural representations of items in working memory.

The researchers examined the recordings to identify patterns of activity that are associated with correct responses and swap errors. They then compared these patterns with those that would be expected, based on previous studies, if the monkeys were correctly encoding and remembering information stored in their working memory.

Their analyses suggest that the brain responses linked to swap errors emerged before the animals decided which colour to report. Rather than occurring as a result of them forgetting or a failure to correctly encode items in their working memory, they appeared to arise during "selection", when certain items stored in working memory are enhanced at the expense of others (bioRxiv, doi.org/k2ms).

"Everyone assumed there were simpler explanations like failure to encode or forgetting, but this very cool study shows that working memory errors come from a previously unknown source," says Earl Miller at the Massachusetts Institute of Technology.

These results show how the neural processes behind storing and manipulating working memory can be surprisingly brittle, say the researchers. ▮

FG TRADE/GETTY IMAGES

Forgetting what is on the shopping list could be down to "swap errors"

Physics

Sperm caught breaking Newton's third law of motion

Karmela Padavic-Callaghan

HUMAN sperm cells and some microorganisms swim by deforming their bodies in a way that breaks Isaac Newton's third law of motion – and we are closer to understanding how they do it. The findings could inspire tiny swimming robots that also violate this law.

Newton's third law can be summed up in the phrase "for every action, there is an equal and opposite reaction". This reciprocal relationship means that as you push against a wall, the wall pushes back against you.

Now, Kenta Ishimoto at Kyoto University in Japan and his colleagues have studied the swimming of human sperm cells and *Chlamydomonas* algae that disobey this law. Both propel themselves using slender, hair-like filaments called flagella.

The researchers found that these flagella have a property, dubbed "odd" elasticity, that allows them to wave without losing much energy to the surrounding fluid. This helps propel the cell forward in a so-called non-reciprocal way, meaning they violate Newton's third law.

The researchers quantified the elastic property, calling it the odd elastic modulus. The higher this number, the more a flagellum can wave without the surrounding liquid suppressing its motion (*PRX Life*, doi.org/kz9z).

Being able to calculate the odd elastic modulus and similar properties could help create a "dictionary" of organisms that are capable of non-reciprocal movement, says Piotr Surówka at the Wrocław University of Science and Technology in Poland.

Ishimoto says his team's approach could also inform the design of artificial swimmers, helping researchers build small, elastic robots that can also violate Newton's third law. ▮

Artificial intelligence

Hundreds of chatbots could show us how to make social media less toxic

Chris Stokel-Walker

A SOCIAL media algorithm designed to bridge the gap between people with different political views could reduce the toxicity of online discourse and promote better conversations. It seems to be effective – at least in tests on artificially intelligent chatbots.

Petter Törnberg at the University of Amsterdam in the Netherlands and his colleagues created 500 chatbots powered by a large language model (LLM) and got them to interact with each other as if they were on a social media platform. The bots were encoded with personas designed to be representative of the US population, based on data from the 2020 American National Election Study.

The data included information on the news sources people consume, their demographics, their political beliefs and their non-political interests, such as their favourite TV shows and movies. The LLM was prompted with that data and asked to produce posts that echoed each voice. "LLMs are very good at pretending to be a persona," says Törnberg.

SKORZEWIAK/ALAMY

AI-powered chatbots with different personas can simulate conversations on social media

Those virtual users were then put into three separate social media platforms with a similar design to X, formerly known as Twitter, each dictated by different algorithms. The first showed users the most liked and commented-on messages only from users they follow. Each user in this version followed 30 other agents.

On the second platform simulation, users were shown the most liked and commented-on messages from all users on the platform – exposing them to other political views. X and Instagram Threads have both used a version of this approach in their algorithmically dictated feeds.

The third simulation showed users messages from accounts from all backgrounds, but prioritised messages that had likes from users who were politically opposed to them. Users identified as Republicans were shown posts popular with Democratic users, for example.

The first simulation produced a civil platform with nearly no interaction with supporters of the opposition party. The second showed "much more interaction across the partisan divide, but also much more toxicity", says Törnberg. The third blended high engagement with low levels of toxicity – which could be a model for the future (arXiv, doi.org/k2kn).

Creating representative users in this way is useful, says Noah Giansiracusa at Bentley University in Massachusetts, because a big challenge for academics doing social media research is convincing the platforms they are studying to give up their data.

However, AI-generated facsimiles of people can only get you so far in mimicking real human interaction on social media. "Chatbots can emulate certain personas and political perspectives through prompting, but they don't actually have views or values or even consistent personalities," says Giansiracusa. "We've all felt those strong visceral reactions to content on social media. A chatbot does not experience this."

> "Users identified as Republicans were shown posts popular with Democratic users"

Zoology

Emergence of cicada generation led to a caterpillar boom

WHEN big broods of cicadas emerge every 13 or 17 years, birds are treated to a smorgasbord of fresh food – and this sudden glut has cascading effects on other animals and plants in the ecosystem.

John Lill at The George Washington University in Washington DC and his colleagues have investigated the behaviour of birds in the years before, during and after the emergence of the cicada generation known as Brood X across the eastern US in 2021.

The researchers set out dummy caterpillars made of clay and recorded the telltale marks left by beaks as birds attempted to eat them. In years with no cicadas, about one quarter of the dummies were attacked each week, but during the short few weeks of cicada season, fewer than 10 per cent showed signs of bird strikes.

Lill and his colleagues enlisted bird watchers to observe birds and discovered that more than 80 species were taking part in the all-you-can-eat cicada buffet (*Science*, doi.org/gswjtg).

"They saw owls, swans, herons and even small songbirds whose beak we thought would be too small to eat a cicada," says Lill. "Some didn't recognise the cicadas as food at first, but they eventually figured it out."

M. WEISS/GEORGETOWN UNIVERSITY

Two adult cicadas on a plant in Washington DC, during the 2021 Brood X emergence

That dietary adjustment affected caterpillar populations and the forest at large. The team observed more than twice as many caterpillars during cicada season, and those caterpillars caused twice as much damage to trees and leaves as usual. "In a normal year, birds regulate insect herbivore damage, but that gets disrupted in cicada years," says Lill.

The research gives a preview of what a world with fewer birds might be like, says Lill. "Birds are important for regulating insects in forestry and agriculture," he says. "Without them, there will be more damage to forests and food crops."

David Beresford at Trent University in Peterborough, Canada, says the study highlights how changes to one species can cause ripple effects across the whole ecosystem.

Brian Owens

Neuroscience

Sleepers respond to words they hear

People seem to be able to reply to speech with pre-arranged facial expressions while napping

Clare Wilson

RESEARCHERS have managed to communicate with people who are asleep, which could open up ways to study sleep and dreaming.

In a small study, volunteers occasionally made brief and partial smiles or frowns as they slept in reaction to certain words – and their responses, which had been pre-agreed, were usually appropriate. They had no memory of what had happened when questioned afterwards.

This is the first time such communication has been established in those who aren't one of a rare group of people who can control their dreams, known as lucid dreamers. "These windows of reactivity could pave the way for real-time communication with sleepers," says Delphine Oudiette at the Paris Brain Institute in France.

Oudiette's team made the discovery while developing ways to communicate with lucid dreamers, something the group showed was possible in 2021.

The initial targets were people with narcolepsy, a rare condition that can cause people to suddenly fall asleep. These people are more prone to lucid dreaming.

But when the researchers asked volunteers who don't have narcolepsy and never have lucid dreams to join their study for comparison, they were surprised to find that this group could also sometimes smile or frown in response to cues while they napped, albeit at a lower rate than the lucid dreamers.

> "These windows of reactivity could pave the way for communication with sleepers"

The study involved 27 people with narcolepsy and 21 without it. While the participants were awake, the team asked them to listen to recordings of someone saying either real words or similar-sounding fake ones. Half of each group were asked to smile three times if they heard real words and frown for fake ones, while the rest were told to do the opposite.

Next, participants were hooked up to two sets of sensors – to detect facial movement and to record brainwaves, the latter via an electroencephalogram (EEG), which can show if someone is awake or in various stages of sleep.

Then the participants took a daytime nap. The team played the recordings intermittently as people dozed off, with the volume turned down very low.

In the first stage of sleep, called N1, which typically lasts about 5 minutes, the people without narcolepsy gave a response – whether correct or not – to the recordings about 20 per cent of the time. In later stages of sleep, the response rate was about 5 per cent, and in the deepest stage they didn't respond at all (*Nature Neuroscience*, doi.org/kz6k).

The researchers gave the participants some leeway, recording a positive response if the sleeper moved their smiling or frowning muscles twice or more. "[The task] was hard to perform, even during wakefulness, so we decided to accept any [response] that includes at least two successive contractions of a same muscle," says Oudiette.

When people did respond, their response was the correct one about 80 per cent of the time.

The overall response rate in those with narcolepsy was higher, ranging from 20 to 65 per cent.

The team now plans to analyse EEG recordings to try to identify any brainwave signatures that indicate when people will respond to hearing sounds, says Oudiette. "We could develop tools to detect when these windows will open in real time and then we could send questions right at that moment."

"It's really nice to see this in non-lucid dreamers," says Jonathan Cedernaes at Uppsala University in Sweden. "I think it will be a means for us to peer into what's going on during sleep." ▮

Physics

Upwards lightning shoots out X-rays as it rises to the clouds

LIGHTNING can rocket up from tall towers to the clouds – and now we know that it produces X-rays at the beginning of its ascent.

During a thunderstorm, different parts of a cloud become positively and negatively charged. This leads to a lightning strike, a dramatic electrical discharge that manifests as a column of hot ionised gas and electrons, or plasma, reaching for the ground.

But when charged-up clouds hover over a tall structure made predominantly from a conductive material like metal, lightning can emerge from the building's tip and flash upwards.

Toma Oregel-Chaumont at the Swiss Federal Institute of Technology in Lausanne and their colleagues have now studied four upward lightning flashes from the 124-metre-tall Säntis Tower, which sits at the top of Mount Säntis in the Appenzell Alps in Switzerland.

The researchers measured electric currents running through the metallic structure and changes in the magnetic field, using an X-ray detector and a high-speed camera to study what was going on.

The measurements showed that X-rays are produced at the very beginning of the lightning's journey upwards as the electricity makes twisting, turning leaps (arXiv, doi.org/kz6h).

TOMA OREGAL-CHAUMONT, ANTONIO SUNJERGA, ET AL.

Lightning can leap up from the 124-metre tower on Mount Säntis in Switzerland

Joseph Dwyer at the University of New Hampshire says the new measurements may offer insights into a rare but even more dramatic phenomenon where thunderstorms produce gamma ray flashes, which are more energetic than X-rays.

Oregel-Chaumon says the array of data the researchers collected could also help test ideas about what electrons and other particles are doing as lightning begins to form, such as the proposal that accelerated lightning electrons hit nearby air particles and "brake" by emitting some of their energy as X-rays. ▮

Karmela Padavic-Callaghan

Technology

Particle accelerator is so small it could fit inside a pen tip

Karmela Padavic-Callaghan

A PARTICLE accelerator that is just 0.2 millimetres long is the smallest device of its kind, and could have medical applications.

Particle accelerators, such as the Large Hadron Collider or those in medical facilities used to treat cancer, speed up particles like electrons using electric fields and magnets. The fields are typically generated using radio waves, which have wavelengths measured in metres or centimetres, and this limits miniaturisation.

Now, Peter Hommelhoff at the University of Erlangen-Nuremberg in Germany and his colleagues have accelerated particles using light, which has a much shorter wavelength, measured in hundreds of nanometres. To do it, they created a silicon "runway" of two parallel lines, each 0.2 millimetres long and containing thousands of 2-micrometre-tall pillars.

The researchers shone laser light on this runway from above while injecting electrons from the side. The light waves from the laser interacted with the pillars to create an electromagnetic field that made the electrons bunch up. These particle clusters accelerated through the structure until they were moving at more than 100,000 kilometres per second (*Nature*, doi.org/kz6d).

When the team constructed a 0.5-millimetre-long version, it could accelerate particles even faster, increasing the energy they carried by 43 per cent. This means the device can be made more powerful while staying small enough to be included on computer chips, says Hommelhoff. It only gives electrons about a millionth of the energy they gain in larger accelerators, though.

"We think we can eventually shrink accelerators so that they will fit into the tip of a pen," says Hommelhoff. "Then, you can really think of new treatment tools for doctors."

Virology

The bird flu sweeping the world evolved in Europe and Africa

Grace Wade

PIERRE CROM/GETTY IMAGES

A man collects gulls killed by bird flu in May in Gouda in the Netherlands

THE virus behind the largest-ever bird flu outbreak originated in Europe and Africa, suggesting that the epicentre of bird flu viruses has shifted away from Asia to other continents.

Since 2021, a subtype of the bird flu virus called H5N1 has infected and killed a record number of both domestic and wild birds across the globe. H5N1 was first detected in China in 1996 and largely stayed in South-East Asia until 2005.

That year, outbreaks occurred in birds across Africa, the Middle East and Europe. The H5N1 virus later re-emerged in 2021, affecting birds in North America, Europe, Asia and Africa. It also spread to some mammals, including a few people.

"Something is different about the mid-2020 and onward viruses than anything we've seen since that 1996 detection," says Richard Webby at St Jude Children's Research Hospital in Tennessee. "So just a huge amount of virus in wild birds, like nothing we've seen before."

To understand the recent spread of H5N1, Webby and his colleagues analysed bird flu outbreaks that occurred between 2005 and 2022. They collected data on the number and location of confirmed bird flu cases worldwide from the Food and Agriculture Organization of the United Nations and the World Organisation for Animal Health. They also obtained genetic information on bird flu viruses using two public databases.

After examining the genetic data, the team traced the H5N1 virus behind the outbreaks that occurred from 2021 onwards to another subtype of the bird flu virus, named H5N8, which originated in northern Africa.

Widespread outbreaks

This virus began circulating in wild European birds in 2019, where it subsequently evolved into the current H5N1 virus. That virus then spread through wild European birds for at least a year before causing widespread outbreaks in domestic and wild birds in many more countries in 2021 (*Nature*, doi.org/kz6j).

"That signals a major change for this particular virus," says Webby. "The epicentre of H5 evolution, which has been South-East Asia, is actually now changing." This suggests that other countries should increase bird flu surveillance efforts, especially those in Africa, where such infrastructure is lacking, he says.

Vigilance is crucial to understanding which bird flu viruses are circulating and how they are evolving or migrating, says Seema Lakdawala at Emory University in Atlanta, Georgia. Knowing this can guide vaccine development and efforts to curb bird flu transmission. "By understanding what is out there, we can prepare ourselves," says Lakdawala.

2019

The year a virus emerged that evolved into the current H5N1

Bird flu can't yet transmit between people. Humans contract it only by interacting with an infected animal. Increased surveillance is thus also important for warning people in affected areas to avoid contact with birds and other animals that may be sick with bird flu, like seals, foxes and bears. Every human infection gives the virus an opportunity to evolve mutations that could help it spread in people.

"If we can identify places of spillover and reduce spillover in humans, we can reduce the potential for a pandemic emergency," says Lakdawala.

Space

Blast of radio waves is 8 billion years old

ASTRONOMERS have spotted the oldest fast radio burst (FRB) ever seen, dating back 8 billion years. It is also the most energetic of these strange, very brief blasts of radio waves that we have spotted.

"The burst has the energy that the sun produces in 30 years," says Ryan Shannon at the Swinburne University of Technology in Australia. "That is enough power to microwave a bowl of popcorn about two times the size of the sun." Shannon and his team say the event, named FRB 20220610A, is three-and-a-half times as energetic as others we have detected (*Science*, doi.org/kz85). These bursts are thought to come from magnetised neutron stars.

The researchers traced this FRB to a distant cluster of galaxies, which means it has been travelling for almost 8 billion years. **Chen Ly**

Health

Hitting snooze won't make you more tired

SLAPPING the snooze button when your alarm goes off may not leave you in a sleepier state than if you just got up straight away.

Tina Sundelin and her colleagues at Stockholm University in Sweden have analysed 31 people, who ordinarily snoozed at least twice a week, while they spent two nights in a sleep laboratory. During the first night, the participants got up when their alarm went off. On the second night, they set their alarm 30 minutes early and hit snooze a few times before getting up.

The researchers found that cortisol levels, which indicate wakefulness, were slightly higher after snoozing, but there were no differences in people's ratings of sleepiness or mood or in their cognitive performance (*Journal of Sleep Research*, doi.org/kz9t). **Sara Novak**

KONDRATUK ALEKSEI/SHUTTERSTOCK

Zoology

Warm seas blamed for disappearance of snow crabs

MORE than 10 billion snow crabs in the sea off Alaska have disappeared in recent years. Marine biologists have now linked the population crash to a 2018 heatwave, which may have led to mass starvation.

Since 2018, the snow crab (*Chionoecetes opilio*) population in the eastern Bering Sea has been rapidly declining. The Alaska Department of Fish and Game cancelled the 2022 and 2023 snow crab harvests to conserve the remaining population.

Cody Szuwalski, who is at the National Oceanic and Atmospheric Administration in Washington DC, and his colleagues have analysed annual surveys of the Bering Sea and found that between 2018 and 2021, the crab population fell by 10 billion, or around 90 per cent. "That's the lowest levels we've ever seen them," says Szuwalski.

The beginning of the drastic drop coincided with a heatwave in the Bering Sea during 2018 and 2019.

Snow crabs fare best in cold waters. By modelling the crab population and its larger energy requirements in warmer water, the team found that there wasn't enough food to support a warmer, hungrier crab population (*Science*, doi.org/kz8x).

"We think that starvation played a big role in the collapse," says Szuwalski. "From 2017 to 2018, the calories they needed quadrupled."

Warmer waters may have also increased the species' susceptibility to disease, contributing to the collapse.

Szuwalski says there has been a small regrowth in snow crab numbers, but it will take many years of cooler conditions for the population to recover. **CL**

Really brief

ESA/DLR/FU BERLIN/G. MICHAEL

Surprising seismic activity on Mars

The most powerful quake we have recorded on Mars was produced by tectonic forces from within its crust, not a meteor impact. The magnitude-4.7 quake was detected by NASA's InSight lander in 2022 and hints Mars is more seismically active than we thought (*Geophysical Research Letters*, doi.org/gsv8cs).

Keep servers warm to save energy

Data centres could save up to 56 per cent of the energy used on cooling by running at 41°C (106°F) rather than at 22°C (72°F), without significantly affecting performance (*Cell Reports Physical Science*, doi.org/kz9v). Operators normally aim to keep data centres cool to prevent overheating and potential damage.

Hurricanes getting stronger, faster

An analysis of all tropical storms in the Atlantic between 1971 and 2020 shows that hurricanes are, on average, growing stronger, faster. This is what theory predicts as a result of global warming, because tropical storms are powered by warm sea water (*Scientific Reports*, doi.org/kz9w).

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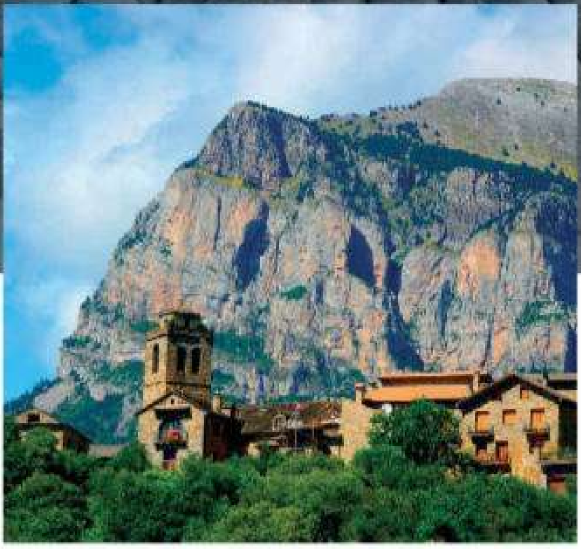

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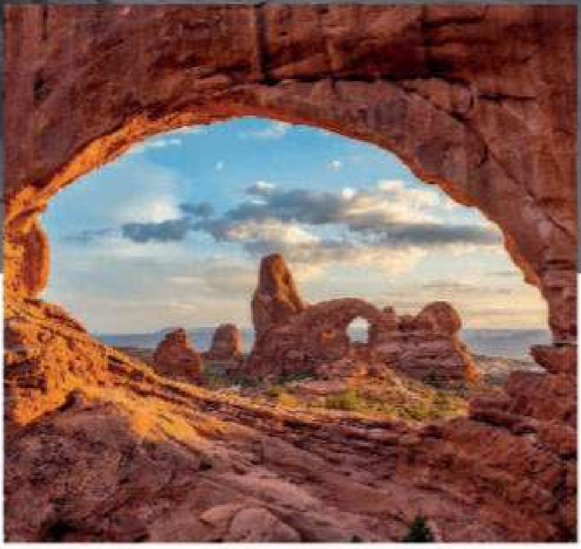

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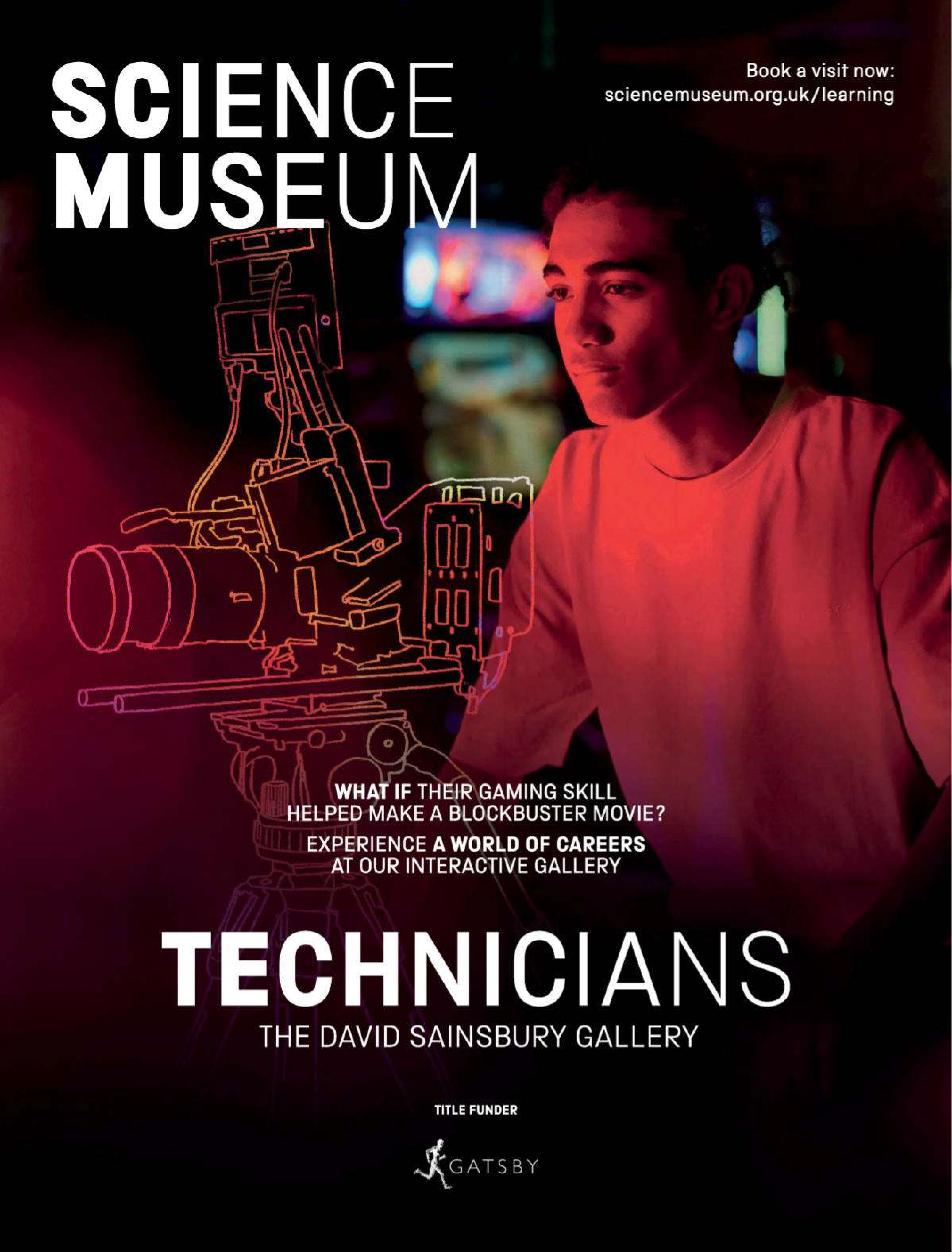

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Views

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Courageous seals cause a shark to beat a hasty retreat p24

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How have women shaped the course of evolution? p26

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Bethan Ackerley digs into *Lessons in Chemistry* p28

Letters
We should try turning lab-grown meat tech to other uses p29

Comment

Building our future

Let's lose old stereotypes about engineering, because attracting new talent is crucial to meeting net-zero goals, says **Dr Hayaatun Sillem**

MICHELLE D'URBANO

DEBATE around net-zero ambitions continues to consume the global news agenda, from UK prime minister Rishi Sunak's changes to key green targets, to estimates that a full net-zero transition across US infrastructure will cost over $100 trillion. Despite uncertainties, one stark reality is already clear: we lack sufficient numbers of engineers to deliver even the commitments already enshrined in legislation. While it rarely makes the headlines, this issue will be defining if left unaddressed.

The green transition requires decarbonisation across every sector, and innovative engineering solutions are needed to achieve this. From breakthroughs in biodegradable packaging to improvements in electric vehicle charging technology, we need creative approaches to transition to a more sustainable future.

But without a workforce with the necessary numbers of engineers and technicians, these solutions simply can't be delivered. For example, the UK energy sector needs to fill 400,000 roles by 2050, around 260,000 of which will be newly created. In the housing sector, retrofitting will require the recruitment of 30,000 technicians each year at its peak in 5 to 10 years' time. This is on top of "business as usual" needs.

If we are to address this deficit, we must focus our efforts on attracting more people into engineering – a task that is proving no mean feat. Job site Indeed reports that engineering vacancies are among the hardest-to-fill roles in the UK. While veterinary surgeons topped the list, mechanical engineers came second, electrical engineers fourth and civil engineers fifth.

The key to resolving this quandary is overturning outdated perceptions of engineering and demystifying routes into it as a career. For example, contrary to popular belief, maths and physics aren't always prerequisites for studying engineering, but this misconception obstructs at least some people from treating it as a career option. There is much work still to be done to connect those considering an engineering career – and those influencing their choices – to the reality of the skills that underpin success in engineering.

Promoting the fact that skills such as curiosity, problem solving and creativity are essential to engineering roles will help more people realise that they may well have an "inner engineer". We need to dismantle the stereotypes that plague the industry, such as hard hats and greasy rags, and show a truer representation. Engineers are just people who have followed what they love – whether that is sports shoes, disaster relief or bath bombs – into engineering.

Adapting the language associated with engineering will also be essential to changing its reputation. The damaging and misguided tendency to divide people into "creatives" and "scientists" still persists, despite evidence this is an utterly false dichotomy. Successful engineering certainly combines creativity with technical ability.

This unhelpful division also has an impact on the willingness of female students to consider engineering careers. Stereotypes around "male" and "female" skill sets often prevail, leading to UK engineering and technology degrees attracting the lowest proportion of female students in the academic year 2021/22, compared with other courses.

Many professions and skill sets are needed to navigate a transition to a net-zero society. But doing so will be impossible without a sufficient number of skilled engineers. It is therefore in all our interests to tackle the skills and diversity deficit that engineering currently faces. To do this, we need to be better at communicating the scale of the job opportunities within the transition to net zero, and at demonstrating engineering really is for everyone. ■

Dr Hayaatun Sillem is chief executive of the Royal Academy of Engineering, UK

This changes everything

Don't click on the war

Online celebrity culture, such as the saga of movie stars Will Smith and Jada Pinkett Smith, is the ultimate counterprogramming in a time of conflict, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Terraformers* and they are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

DESPITE the implosion of social media, I still get all my news online. I start the day with podcasts from National Public Radio; later on, I follow up with a science or tech podcast when I go out for a walk. I read newspapers and magazines on my desktop computer throughout the day. All of which is to say that I cannot go online to do my job as a writer without also getting inundated with the latest terrifying images and stories from the wars in Gaza and Ukraine.

It hurts. The facts hurt, the disinformation hurts, the knowledge that both conflicts could lead to a much bigger war hurts. It feels like I have more agency over what is happening if I get news updates every hour. At the same time, I want to shut it out. I seek other kinds of media that will distract me so thoroughly that the wars recede for a moment. Perhaps that is why I recently spent so long following the very online saga of movie stars Will Smith and Jada Pinkett Smith.

Both are huge celebrities associated with big science-fiction franchises: Will Smith was in, among other things, the *Men in Black* movies and *Independence Day*; Jada Pinkett Smith had standout roles in the *Matrix* franchise and the Batman series *Gotham*. They are sort of action-sci-fi royalty for nerds like me. But Pinkett Smith also has a second career as a reality TV star, helming a weekly streaming show on Facebook called *Red Table Talk* with her daughter and mother.

For five years, *Red Table Talk* revelled in radical family honesty, featuring a lot of awkward moments as the Smith family sat at the eponymous red table and worked through infidelity, gender issues, intergenerational squabbles and more. It was classic online influencer content, full of performative confessions that felt messily intimate, yet also precisely tuned to keep the family in the public eye.

Facebook cancelled the show in April, but that wasn't the last we would hear about the Smiths' public/private lives. Earlier this month, Pinkett Smith released her autobiography, which contained a bizarre bombshell. It turned out that she and Will Smith hadn't been a couple since 2016. That meant *Red Table Talk*'s entire run was based on a fake relationship between the two. The raw realness was just theatre. Of course, I know that reality TV isn't real and that many celebrities have PR relationships to gin up interest in their work. Still, this seemed like an extreme example – a long game without any payoff.

> **"I wanted to optimise the search engine of my own mind, to find results about movie stars rather than wars"**

I dived into this gossipy fluff as I tried not to click on the wars. I wasn't the only one – Pinkett Smith's revelation made international headlines. But why was this fake celeb marriage such a potent distraction from real news? As podcaster Brittany Luse explained on *It's Been a Minute*, PR relationships take place within webs of political and economic intrigue. Luse described how Taylor Swift's new relationship with American football player Travis Kelce helped change search engine results on her name. Some fans had been outraged by how much pollution Swift was generating with all her private jet trips. But after she attended a New York Jets game Kelce played in, searches on "Swift jet" all returned gossip about the couple rather than reports of her private jet use.

Swift's new relationship distracted audiences from focusing on how their favourite singer is helping to destroy the environment. Obviously, it doesn't hurt that any kind of romance makes headlines, too. The same goes for high-profile break-ups like those of the Smiths. After all, the more people pay attention, the more money celebrities stand to make – and Pinkett Smith has a book to sell.

Still, there are patterns to the way we pay attention to media that aren't dictated by Machiavellian PR schemes. Sometimes, we manipulate ourselves. I went down the celebrity gossip rabbit hole because I wanted to optimise the search engine of my own mind, to find results about dysfunctional movie stars rather than violent military action. After reading timelines of the war in Gaza, I read timelines of the Smiths' fake marriage. There was an astonishing structural symmetry to media accounts of both – twists and turns, fake-outs and blow-ups.

The overall effect was that everything I read online took on a surreal, fictional quality. It was both soothing and toxic, like drinking too much cough syrup. I clicked through more and more pictures of Pinkett Smith, looking into her perfect face, wondering why she had lived a lie for so long and what she had got out of it. I didn't click on the war. I clicked on pictures of Pinkett Smith's alleged boyfriends, and then rewatched a clip of her as the badass Niobe fighting evil robots in *The Matrix Revolutions*. I didn't feel better.

Still, for a few minutes, I didn't click on the war. ▮

Annalee's week

What I'm reading

Premee Mohamed's novella And What Can We Offer You Tonight, *about an undead courtesan fighting for justice.*

What I'm watching

The season finale of Star Trek: Lower Decks, *the best Star Trek series on right now.*

What I'm working on

A syllabus for a media studies class I'm teaching next year.

This column appears monthly

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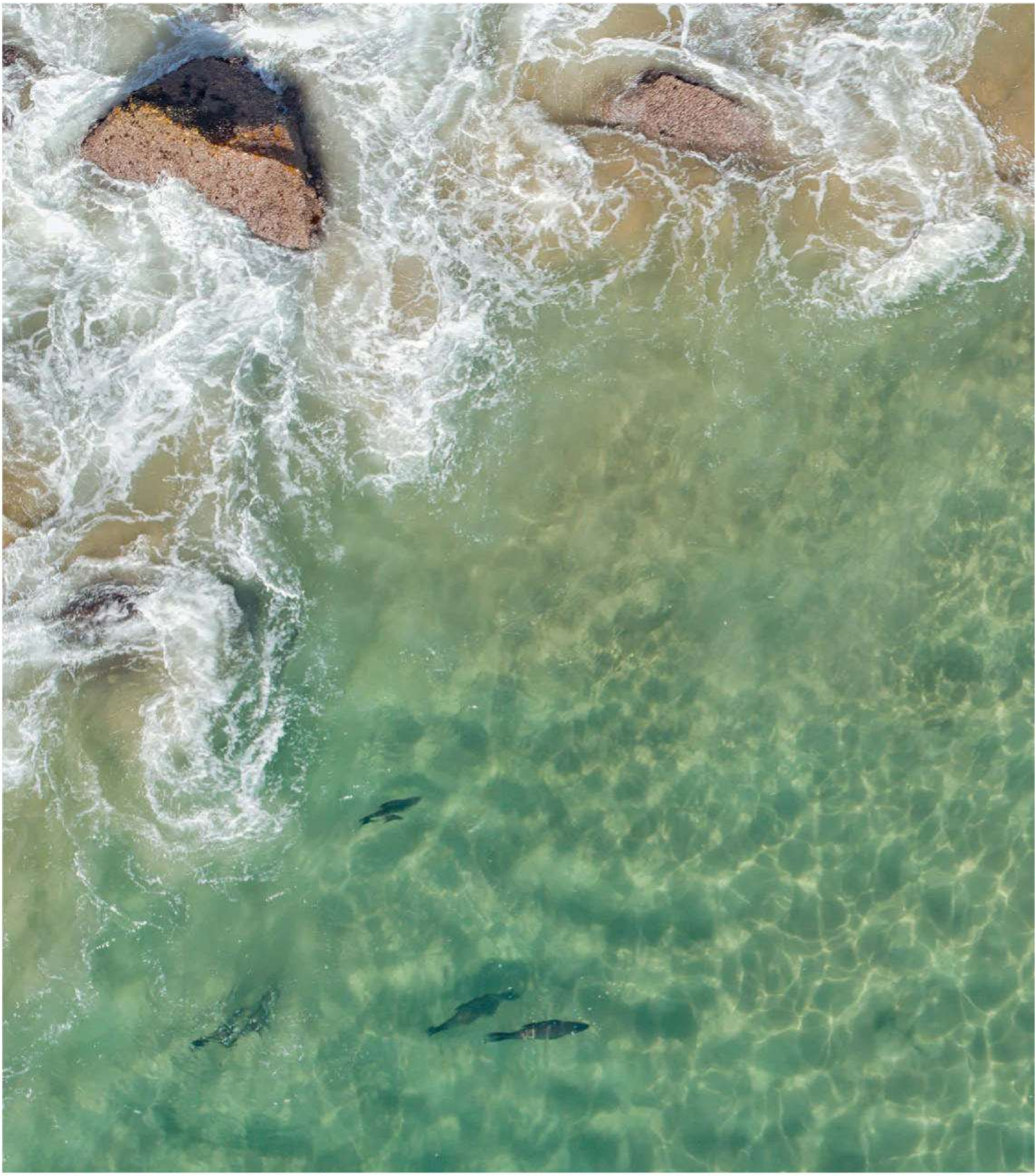

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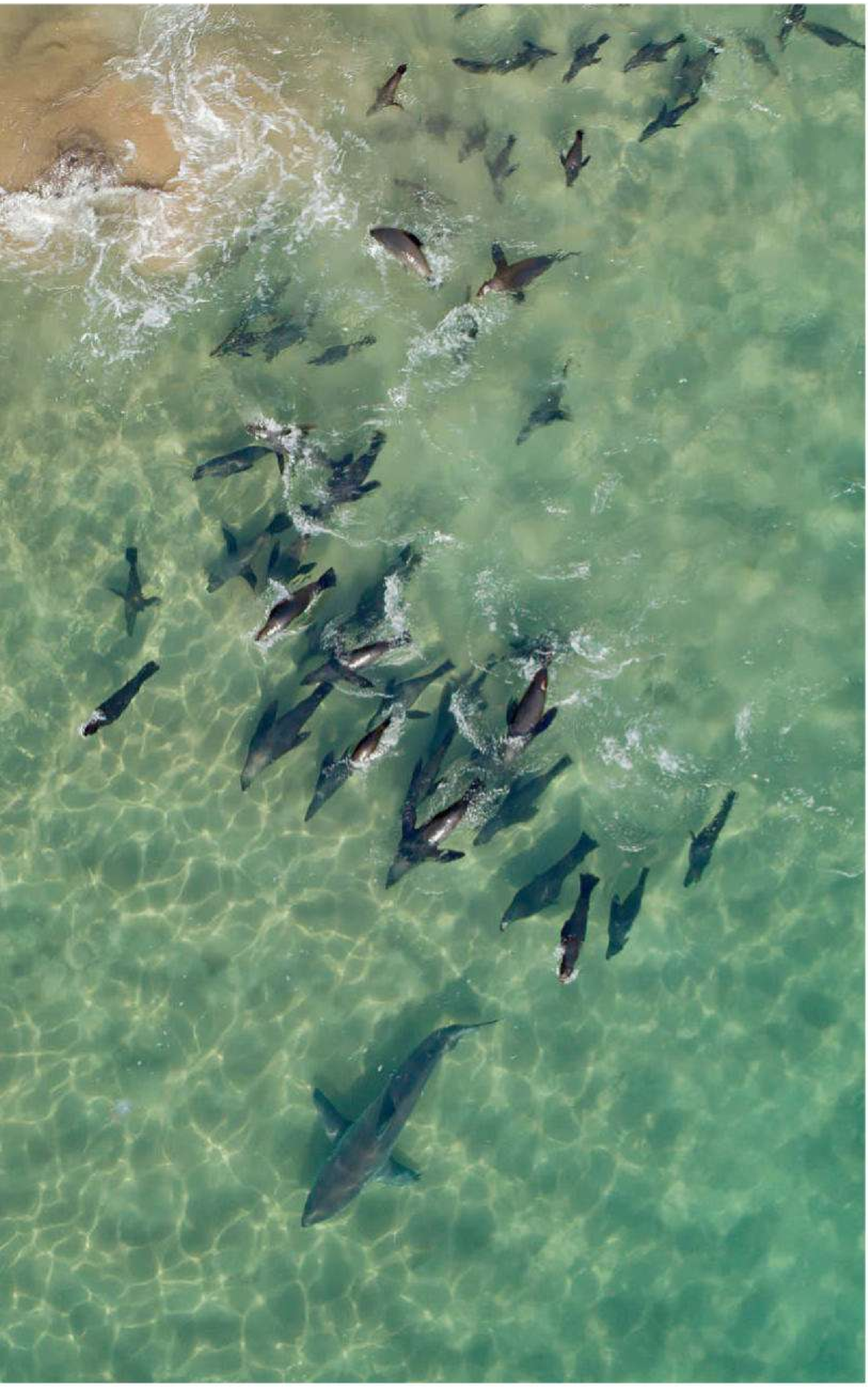


On the run

BBC Books
Penguin Random House

THE final series in the *Planet Earth* trilogy, the BBC's smash-hit nature documentary narrated by David Attenborough, reaches UK screens this month.

From coasts to deserts to cities, *Planet Earth III* explores the diversity, drama and vulnerability of the natural world through eight gripping episodes shot over the course of five years.

During this tense scene off the Robberg peninsula on the Indian Ocean coast of South Africa, a great white shark prowls the waters for vulnerable Cape fur seal pups, which are making their first tentative dips into the water. The shark is seeking out their fatty, energy-rich blubber, which will sustain it for days, or even weeks, on end.

But while this iconic predator initially appears to have the upper hand (the slow, clumsy pups are an ideal target), its cover is soon blown.

As the image shows, adult seals have spotted the shark. Instead of fleeing, they turn on it and mob it, rallying more seals to the shark's location and eventually chasing it away from the area. The pups, meanwhile, learn a valuable lesson about the dangers lurking in the ocean.

It is an "engaging, if not outright dangerous, version of 'early years learning'", write Matt Brandon, Michael Gunton and Jonny Keeling in *Planet Earth III: Our world at the dawn of a new age*, a book accompanying the series that features more epic shots and descriptions from the show.

Planet Earth III airs in the UK on 22 October.

Gege Li

The ascent of woman

Was culture made by mothers? What is menopause? Did sexism help women? **Alexandra Thompson** reads an account of women as evolutionary agents

Book
Eve
Cat Bohannon
Penguin Books

DID humans evolve to be sexist? Without contraception, suppressing women may have been an effective way of keeping birth rates under control. But any "benefits" of sexism (painful as that is to write) may have been overtaken by the knowledge that culminated in gynaecology, as humans learned to help each other through the process of big brains travelling through narrow pelvises. Perhaps our ancestors also used that knowledge to time births with harvests or help mothers and babies survive if plentiful environments gave rise to mass mating.

These are some of the – occasionally contentious – points argued by Cat Bohannon, an author and researcher, in *Eve: How the female body drove 200 million years of human evolution*, with this period covering the time since the emergence of the earliest known mammals.

While women now wear many hats – often juggling parenthood with careers – prehistoric roles are thought to have generally been more traditional. The effects show up in many ways, such as the fact that although fathers and other caregivers can play a huge role in a child's upbringing, it still tends to be mothers who sow the seeds of a child's vocabulary, says Bohannon.

As she argues, a human brain's capacity to learn speech peaks around the age when, for many of us at least, we are frequently in our mother's arms as she feeds or cuddles us, making women "language machines".

What comes from language? Storytelling, for one thing – a specifically human trait that Bohannon lays at the feet of mothers. At times, her book flits between non-fiction and fiction, with Bohannon imagining an exhausted female hominin (maybe a prehistoric member of our species or a Neanderthal) trying to soothe her distressed baby with a yarn. None of this is too surprising, given Bohannon's PhD covered the evolution of narrative and cognition

She goes on to wonder if what started as humble stories ended up giving birth to religions, fables and legends, which, in turn, shaped art, burial rituals, laws, marriages and social hierarchies globally. This, however, is quite a leap and one can't help but think it oversimplifies the cultural forces that also moulded how we live.

Of course, language enables wisdom to be passed down too, which Bohannon links to menopause, a curious biological process. If organisms evolved to optimise the passing on of their genes, why would women lose this ability at 51 (the average age of menopause in high-income countries)? The menopause is rare, with only humans and whales known to go through it.

It is most commonly explained by the "grandmother hypothesis": the idea that women reach an age when it is better for the continuation of humankind for them to look after the children they already have (and their children's children) rather than to keep making new ones.

Unconvinced, Bohannon argues that the menopause arose alongside agriculture and the medicine, social stability and extra food that came with it, all of which helped us to live past our biologically attuned expiration date. "Maybe we didn't evolve to have menopause. Maybe it was a natural side effect of our extending life spans," she writes. Having older people around would have been useful because they could pass on wisdom learned in their younger years, such as how to survive severe droughts.

"Bohannon wonders if what started as humble stories gave birth to religions, fables and legends"

This is difficult to unravel and perhaps creates more questions than answers. Is Bohannon saying the menopause somehow helps women dodge the grave? Is it that women are inherently better communicators than men, so we want them to stick around and pass on their wisdom? Or is she arguing that pregnancy can be dangerous and there comes a time when it isn't worth the risk given the value of a sage older woman? The arguments feel muaddled and surely Bohannon should have tried to invalidate the grandmother hypothesis too?

Putting her menopause argument to one side, the points raised in *Eve* usually make sense, though they often feel theoretical. Yet when trying to unpick evolution, with fossils only offering a certain amount of help, theorising may be our best shot.

As for whether sexism evolved, like many topics in the book, the jury is still out. It will be fascinating to see how the vote goes.

Eve by Lucien Lévy-Dhurmer, a painter in the symbolist tradition

DEAGOSTINI/GETTY IMAGES

From black to white holes

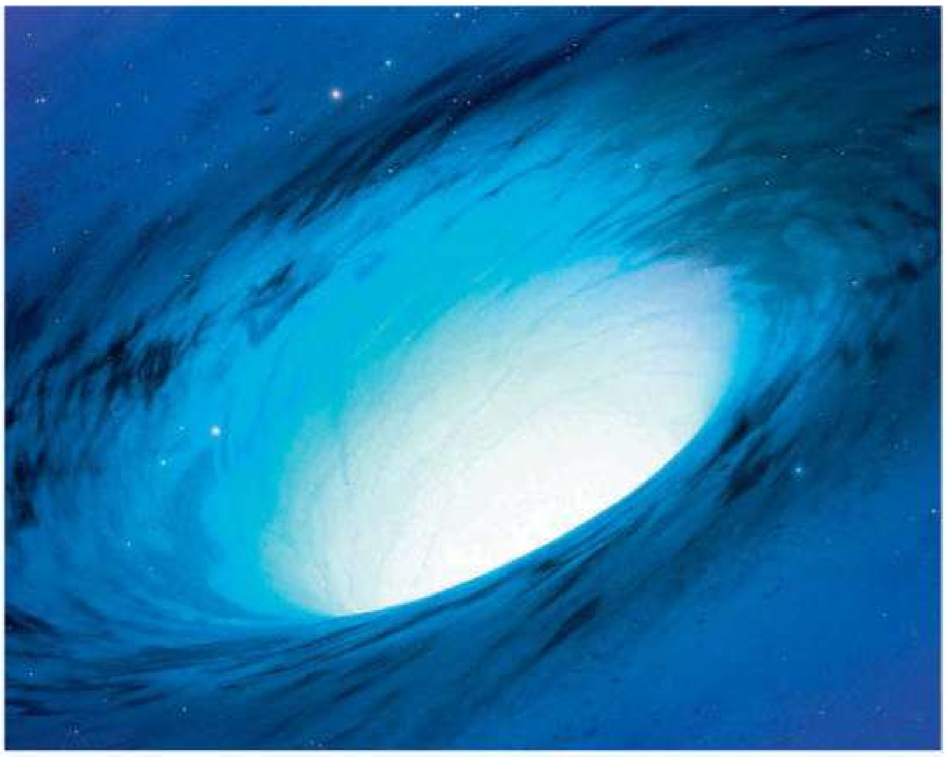
Carlo Rovelli's latest book takes us on a journey into the centre of a black hole – and back out again, discovers **Abigail Beall**

Book

White Holes

Carlo Rovelli

Allen Lane



MARK GARLICK/SCIENCE PHOTO LIBRARY

White holes may be the time-reversed opposite of black holes – if they exist

WHAT happens if you fall into a black hole?

It is one of the most intriguing and complex questions ever conceived. Black holes are places where, at their heart, general relativity breaks down. They are objects that even Albert Einstein thought wouldn't exist in the universe. Yet we know that they do: in the past few years, we have even captured images of them.

I imagine that, like many of us, theoretical physicist Carlo Rovelli was amazed when the first picture of a black hole was released in 2019. But for him, the image was perhaps more meaningful. "I'd studied black holes all my life, without knowing if they truly existed or not," he writes in his latest book. "Here is the visual evidence, something I could never have imagined when I was a university student and was first charmed by these strange phenomena."

Now, imagine black holes going backwards in time. Instead of matter falling into them, everything inside them must leave. These are white holes – the subject, and title, of Rovelli's new book.

Over the past few years (including in previous *New Scientist* book reviews), Rovelli has been called "the poet of physics". This is a title he very much lives up to in *White Holes: Inside the horizon*, which feels more like an ode to the biggest questions in physics – concerning stars, black holes and the nature of time – than any kind of conventional popular physics book.

Perhaps it is the book's length: at a refreshing 150 pages, it can be consumed in a single sitting. Or maybe it is the references to *The Divine Comedy* by Dante peppered throughout the book. Either way, the poetic nature of *White Holes* makes for an enjoyable and enlightening read: great for anyone who likes to indulge in musings about extreme physics that border on the existential.

Much like *The Divine Comedy*, *White Holes* is a journey that takes place in three parts. But instead of the depths of hell, Rovelli plunges us into a black hole. We venture to a place where gravity is so extreme that nothing, not even light, can escape, "where time appears to slow until it stops, and space seems to end", he writes.

Down we go, through the event horizon, dispelling some common misconceptions about the meaning of words like singularity along the way. What results is one of the clearest pictures I have encountered about the physics inside these extreme objects – and I have read a lot of descriptions of black holes.

There are some detours en route, although Rovelli is gracious to any readers who want to stick closely to the parts about black and white holes: "you can always skip ahead if you are a hasty reader", he writes. We learn about the conceptual leaps taken by some of history's most celebrated scientists, hear Rovelli's own experience of developing the idea of white holes with his colleague, Hal Haggard, and consider free will and the flow of time.

Ultimately, though, the idea at the heart of the book is simple: white holes could exist in the universe.

This concept will be so alien to most people that Rovelli's book could easily have become very unsettling. But by introducing the concept of black holes as something many physicists doubted the existence of, even a mere 20 years ago, Rovelli opens readers' minds to the possibility, and the hope, that their counterparts exist.

You probably won't ever fall into a black hole (or exit a white hole), but reading this might be the next best thing.

New Scientist *recommends*

David Stock
Head of editorial video
London, UK

This week, I've visited two new photography exhibitions in London that challenged me to think about science in very different ways.

First up was **Wildlife Photographer of the Year** at the Natural History Museum, which filled me with awe at the rare sight of fireflies lighting up the night sky, Nubian ibex at dusk in Israel (pictured) and the spores of a parasol mushroom dispersing in a Greek forest. But since much of the natural world is under threat, prepare to be reminded of its fragility – and to leave with a desire to do more.

AMIT ESHEL/WILDLIFE PHOTOGRAPHER OF THE YEAR

On a very different spectrum, literally, is photographer Hiroshi Sugimoto's retrospective at the Hayward Gallery. This showcases his most recent project, **Opticks**. Inspired by Isaac Newton, Sugimoto built a prism to split sunlight in New York and in Tokyo, then photographed the results. The red, blue and yellow in his images are striking, yet subtle. And the gallery is a good place to contemplate physics, photography and the inquisitive mind.

The TV column

Cooking up a storm *Lessons in Chemistry* is the story of a woman scientist frustrated by her times who becomes the host of a TV cooking show. The series takes a while to find its stride, but patience will be rewarded, says **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on Twitter @inkerley

TV

Lessons in Chemistry

Lee Eisenburg

Apple TV+

Bethan also recommends...

TV

The Hour

Amazon Prime Video

As a teenager, I was obsessed with this BBC drama about a 1950s news show at, where else, the BBC. Tune in for scandal, espionage and Bel Rowley (Romola Garai), producer extraordinaire.

Mad Men

UKTV Play (UK); AMC+ (US)

Has there ever been a sleeker series than this story of the men – and women – at the heart of the "golden age" of advertising? After watching, read Mad Men Carousel *by Matt Zoller Seitz, a terrific compendium of TV criticism.*

MICHAEL BECKER/APPLE TV

Chemist Elizabeth Zott (Brie Larson) ends up hosting a cooking show

IN TV, as in life, women scientists have been served poorly. Too often, they have been the butt of the joke, a sexy sidekick or a token face in a crowd of men (see *The Big Bang Theory* for examples of all three). Thank God for outliers like Elizabeth Zott (Brie Larson), the brusque, brilliant scientist at the heart of *Lessons in Chemistry*.

This eight-part Apple TV+ series based on the hit novel begins in 1951, when Elizabeth is a lab tech at the fictional Hastings Research Institute. Unable to work as a chemist because she lacks a PhD, she partners with Calvin Evans (Lewis Pullman) to research the origins of life. He is a maverick whose work is tipped for a Nobel prize, and he becomes her lover.

When she is later fired from the lab (for reasons I won't spoil), she becomes the host of a cooking programme called *Supper at Six*, through which she explains how chemistry can be applied in the kitchen – and how important women's unpaid labour truly is.

You would be hard-pressed to find a premise more suited to my tastes, so I was disappointed when the opening episodes were somewhat lacklustre. The first two are hamstrung by the need to establish Calvin as a difficult man with a singular intellect. In these episodes, the dialogue is crammed with molecular metaphors, allusions that quickly cloy in the mouth. I was expecting an effervescent drama; instead, I was consuming something half-baked.

> "The show reflects the reality for many women – their research could be blocked, downplayed or stolen"

Thankfully, though, the version of *Lessons in Chemistry* I craved did eventually materialise. Elizabeth's relationship with Calvin becomes one poignant thread in a larger narrative. Professionally and personally, the pair have (sorry) "chemistry". But her other partnerships, such as her working relationships with TV producer Walter Pine (Kevin Sussman) and secretary Fran Frask (Stephanie Koenig), are far more compelling.

The 50s-era sexism Elizabeth endures is enraging: she spends her days making coffee and is made to enter an interdepartmental beauty pageant. Seeing her secretly do her work, stealing chemicals and running experiments in the women's toilets, is a frustrating glimpse of the barriers women scientists faced in reality.

As for how well *Lessons in Chemistry* depicts the scientific world of the 1950s, people far more qualified than I am, such as scientists Ricki Lewis and James Cooper, have already done this for the book. But there are moments when you wonder, for example, if the show is set in a world where researchers such as Stanley Miller and Harold Urey (who provided the first evidence for the "primordial soup" hypothesis of the origin of life) never existed.

The show is better elsewhere, for instance at depicting the shadowy workings of institutions, where women's research could be blocked, downplayed or even stolen. Sadly, this reflects reality for many women in science, from Alice Ball to Chien-Shiung Wu.

Elizabeth's second act as a TV personality is also mired in misogyny. This makes the scenes where she addresses her acolytes – reminding them, for example, that she stands proudly with the "overlooked workhorses of the kitchen: women and baked potatoes" – all the more thrilling.

By its close, the series has a better handle on what it wants to say about science and women's fundamental importance to it. *Lessons in Chemistry* is a reminder that in science, cooking and even TV, sometimes it takes patience for things to come together. ▮

Editor's pick

Try turning lab-grown meat tech to other uses

14 October, p 21

From Richard Grimmer, Trowbridge, Wiltshire, UK

Brian Kateman argues that lab-grown meat firms should focus on staple foods before they produce versions of exotic meats. In this way, we can increase public acceptance of cultured foods and reduce the adverse impacts of animal farming.

Surely the effort involved in persuading people to eat lab-grown chicken and beef would be better spent persuading them to eat another form of protein altogether, one that is already available, palatable and healthy: beans!

Meanwhile, the technology used to grow animal muscle tissue could be redirected to other animal tissues, those used in traditional medicines that contribute to illegal animal trade and poaching of endangered species. How about growing rhino horn, pangolin scales or leopard bones and putting the poachers out of business?

More views on the many microbiome claims

7 October, p 30

From Lynton Cox, Stamford, Lincolnshire, UK

Being a microbiologist, I get tetchy about some claims made of the colonic microbiome. I concede its importance in young infants and possibly in obesity. Undoubtedly, some evolutionary adaptations have led to many interactions with it. But calling these critical or of prime importance is somewhat overdoing it, in my opinion.

The "elephant in the room" is a whole cohort of many thousands of people, such as myself, who have had their colon removed through total colectomy with ileostomy – and live happy and fulfilled lives of normal span without ill effects. Perhaps more could be learned from those in whom the colonic microbiome is absent than from those in whom it is present. I have seen no mention of this negative control group anywhere.

From Peter Rogers, Bristol, UK

Claims made about our gut microbiome and health greatly exceed the causal evidence. It is telling that the European Food Standards Agency hasn't, to date, approved any health claims for probiotics, foods or supplements that intentionally contain live bacteria. Its decisions are based on the sum of evidence reviewed by independent experts – clearly, they aren't convinced.

On the other hand, extraction of calories from dietary fibre by gut microbes is an advantage, at least if calories are in short supply. But it is harder to understand why evolution would have left our central nervous system, and hence our mental health and behaviour, vulnerable to changes in our diet or its associated microbiota.

The reasons why native plants can be a better bet

30 September, p 44

From Ben Haller, Ithaca, New York, US

Having read James Wong's take on native versus non-native plants, I agree that more research on this is needed, but I wish he hadn't attributed a preference for native plants solely to "cultural bias". In fact, there are good reasons to think that native plants will tend to be better.

This comes down to co-evolution and co-adaptation: native insects, birds and other organisms have evolved together with native plants. They have deep evolutionary synergies based on flowering time, scent, colour and many other attributes. Some insects will lay their eggs only on native plants; some birds will forage and nest only, or preferentially, in native trees. These synergies haven't evolved with non-native plants.

Legacy may bring other benefits too

14 October, p 40

From Tim Stevenson, Great Missenden, Buckinghamshire, UK

Conor Feehly writes interestingly about the psychological reasons for "the legacy paradox", but omits possible evolutionary ones. Striving to be remembered by future generations may get you noticed by your contemporaries, enhancing reproductive success, thereby propagating the putative LEG-AC.Y gene.

Dig deep for the perfect moon base

30 September, p 12

From Mark Kaminsky, Sunnyvale, California, US

When it comes to a perfect site for a moon base, solar radiation can be a danger on the surface. If we could find a cave big enough, that would be a good solution. But lunar dust makes it hard to dig a hole in a conventional way. Some suggest drilling a hole, dropping an explosive in and setting it off at the bottom. Using robots to build a base before we launch people could cut risks further.

At this rate, we will fail to meet net-zero goal

30 September, p 13

From S W Shaw, Kendal, Cumbria, UK

In 2020, as part of the UK's push for net zero, the government set a target of 600,000 heat pump installations per year from 2028. However, there are over 20 million domestic gas boilers in the UK with an average life of about 15 years, so about 1.5 million new ones are needed annually. After 15 years of installing 600,000 heat pumps per year, 9 million homes will have converted from gas, but conversion then ceases as the first tranche of heat pumps whose useful life has ended need to be replaced. Installations and life-cycle replacements have to exceed 1.5 million a year for the transition to succeed.

How does free will apply to an artist?

30 September, p 32

From Bonita Ely, Sydney, Australia

I apply conflicting theories about free will to myself – do we have agency over our actions, thoughts and imaginings, or are we the result of a "zillion" influences? This gets tricky for artists like me, with imagination, lateral thinking, heightened aesthetic sensibilities, creativity, emotions and originality thrown into the pot.

We can beat the creeping threat of sea level rise

Letters, 7 October

From Eric Kvaalen, Les Essarts-le-Roi, France

Guy Cox can't see civilisation surviving 6 to 9 metres of sea level rise. It can. Most land and many great cities are higher than that, so we would still have plenty of room. In any case, it would take centuries for the sea to rise that much, and most buildings don't last that long anyway, so new buildings would simply be built on higher ground. ▮

For the record

- **The company that created the "mammoth meatball" is simply called Vow (14 October, p 21).**
- **It was Robert Stewart of San Francisco, California, who contributed to a recent Last Word (16 September).**

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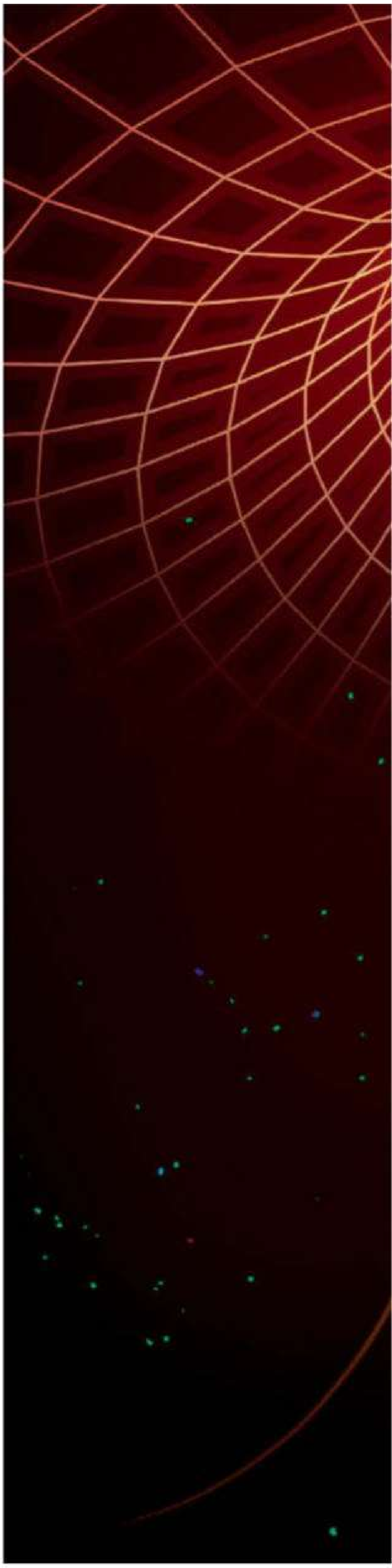
In search of quantum gravity

The question of what space-time is made of, and whether it is quantum or classical, is among the biggest in physics. These experiments could finally crack it, says **Lyndie Chiou**


PABLO HURTADO DE MENDOZA

IF YOU could empty the universe, what would be left over? The underlying structure of the cosmos is called space-time, and it is often likened to a fabric. But "space-time fabric is a science-fiction term", says Jonathan Oppenheim, a physicist at University College London. There is no consensus about what it really means.

In classical physics, namely in Albert Einstein's general theory of relativity, the fabric of space-time doesn't exist on its own. Instead, space-time is intertwined with – and shaped by – mass and energy, giving rise to gravity. Most importantly, Einstein's equations are continuous, so, in the classical view, the fabric must be smooth.

But today, most physicists think that space-time must abide by the rules of quantum mechanics, which govern the behaviour of subatomic particles and fields. In which case, it can be broken down into discrete chunks, or quantised. This would mean that, although space-time appears as a smooth background against which everything in the universe plays out, if you could zoom in sufficiently closely, you would see that it is actually made of something, just like everything else.

The problem is, we still have no evidence that space-time is quantised. It is difficult to prove it one way or another, because what you might imagine as the "pixels" of space-time – its most fundamental constituents – would be so vanishingly small that directly observing them would be impossible.

That leaves us with indirect observations. The good news is that physicists have devised a range of ingenious experiments that could finally settle the question of what space-time is made of, if anything, once and for all.

SLOW NEUTRINOS

When Giovanni Amelino-Camelia and his collaborators published preliminary results hinting at the quantisation of space-time in June, they didn't expect an uproar. But their claims shocked the physics community. "Either they didn't understand or didn't read the paper," says Amelino-Camelia, a physicist at the University of Naples Federico II in Italy.

What they presented were details of their measurements of fundamental particles called neutrinos, which have mass but barely interact with other matter, often originating in distant galaxies. In a classical, non-quantised space-time, neutrinos should travel close to the speed of light. But some quantum theories of space-time predict that it imparts a minuscule amount of drag that would slow down neutrinos at rates depending on their energy.

Amelino-Camelia likens the effect to a glass prism slowing down different frequencies of light at different rates to separate them into a rainbow. Except space-time's drag is far more subtle, so the neutrinos must travel across vast distances if we are to see the effect. "Thankfully, the universe is big enough," he says.

Looking at neutrinos detected by the IceCube Neutrino Observatory, located in Antarctica, Amelino-Camelia and his

colleagues analysed the direction of around 8000 of the most high-energy particles to uncover a handful that appeared to trace back to a common origin. The idea was that if these neutrinos arrived at different times, they must have been slowed down by varying amounts. They had done exactly that – so, by implication, we have seen evidence of quantised space-time.

At least that is the claim. Critics complained about how few data points were used to pinpoint this common origin and that the potential for errors in the measurements wasn't shown. But Amelino-Camelia argued that the time difference between each neutrino detection and its corresponding explosion was so well known that the error margins were too tiny to display. Still, he says, more data is needed. "If our conclusions don't fade away with more data, we will be very lucky," he says. "And we will have lots to talk about."

QUANTUM FOAM

"If I were to zoom in, space and time would be a jumble of fluctuations," says Kathryn Zurek, a physicist at the California Institute of Technology in Pasadena. "When you look over much bigger distances, those fluctuations average out, so what we see is smooth."

Zurek's work focuses on these tiny, hypothetical fluctuations in space-time, which would be the result of putative particles of gravity known as gravitons popping into and out of existence, as many known particles do. She calls it quantum foam, and she is interested in whether, in certain scenarios, it might be possible to see signs of its existence.

She thinks we could, as long as we live in a holographic universe. Roughly speaking, the holographic principle says that although our perception may be 3D, everything within the bulk of the cosmos can be said to emerge from a two-dimensional surface. In May 2022, Zurek showed that, if that is true of our universe, quantum foam fluctuations can be amplified to the point where they become measurable.

On that basis, she has proposed an experiment. It starts with an interferometer, a device using laser light split between two paths that ultimately cross again, revealing interference patterns. In Zurek's proposed set-up, the light would be able to nudge gravitons, which can also be thought of as space-time pixels, into moving together, as if they were one cohesive, fluctuating cloud. She dubs the giant cloud a "pixellon" and says it would be able to alter the trajectories › of light around it, creating a signature in the interferometer.

Zurek cautions that such an experiment is probably a long way off. For one, she is still making sure her predictions don't conflict with known physics. "The theory of gravity is an extremely delicate thing," she says. And secondly, the most sensitive interferometer currently at our disposal, the Laser Interferometer Gravitational-Wave Observatory (LIGO) – the first to detect ripples in space-time called gravitational waves – may not be sensitive enough to detect the effects of quantum foam. "It wasn't designed to do this kind of measurement," says Zurek.

But even if her experiment is run at LIGO and nothing turns up, she has already started working with experimentalists to design a more sensitive interferometer that could.

"This quantum foam is capable of altering the trajectories of light around it"

WEIGHING PHOTONS

Particles of light, or photons, are massless, so we don't normally think that gravity affects them. We should think again, says Zain Mehdi at the Australian National University in Canberra. Einstein showed energy and mass to be equivalent, meaning energetic photons also emit a weak gravitational field, like a mass would. For a sufficiently high photon energy, this warps space-time – an effect that could alter a photon's path in a measurable way.

In June, Mehdi and his collaborators predicted that by driving photons to an extremely high energy, they would interact differently with quantised versus classical gravity. "The [quantised] space-time medium can generate weird effects," says Mehdi.

In one proposed experiment to tap into this difference, a light beam would be split into two halves that are allowed to self-interact. When the two split beams are combined again, their interference patterns would show signatures unique to either quantum or classical gravity. Another set-up would look for a more subtle statistical effect. Due to interactions unique to quantised gravity, a rare event could occur: three photons could annihilate to create a single photon, with a frequency three times that of the originals.

Both experiments would require powerful lasers and special mirrors. "When I tell experimentalists about the [possible] results, I see their eyes popping in a good way," says Mehdi. "But then I tell them they need to improve the laser power and detection efficiency, and that's when their eyes pop in a bad way." The truth is that Mehdi's experiments are beyond our capabilities for the moment. However, advances in similar experiments, like gravitational wave detectors, mean the technology isn't far off.

ENTANGLED MASSES

If gravity is a quantum force, like the three other fundamental forces of nature, it should behave in a quantum way. One way to test that is to see if objects with mass are subject to

Can we conjure space-time from scratch?

SPACE-TIME may not be fundamental. Instead, according to the holographic principle, it emerges from something deeper, like a 3D hologram emerges from a flat surface. The principle says that space-time, and by extension gravity, arises from quantum entanglement.

With that in mind, Monika Schleier-Smith (pictured), a physicist at Stanford University in California, is trying to create space-time from scratch. Her approach simulates a 2D holographic boundary around a universe, which, according to the holographic principle, is enough to encode all the information that describes the universe within. This "holographic duality" says that space-time and the lower-dimensional boundary that it emerges from are equivalent.

In essence, Schleier-Smith's methodology involves tabletop experiments that have the potential to reveal how the holographic principle contributes to phenomena all the way down to those on the smallest scales, where space-time would emerge.

HARRISON TRUONG/STANFORD UNIVERSITY

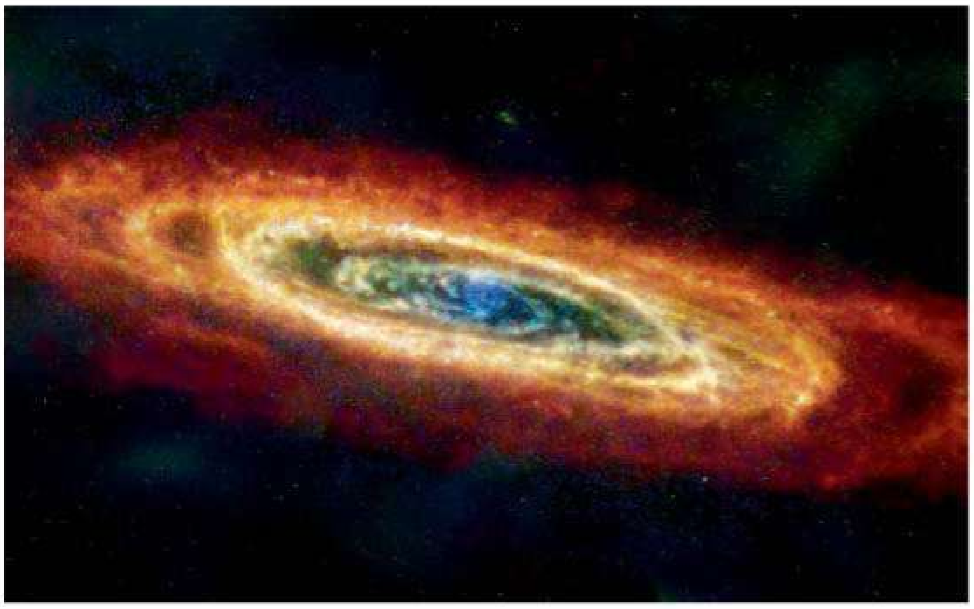
Lyndie Chiou: What is your experimental set-up?

Monika Schleier-Smith: The tools I work with are laser-cooled atoms. We have isolated atoms in a vacuum chamber and we use lasers to bring them to very low temperatures – millionths of a degree above absolute zero. We pin them where we want them and it's essentially a starting point for having a very well-controlled model of a quantum system.

How can you tell the particles are entangled?

We've been studying this idea of holographic duality [by trapping] atoms between two mirrors that form an optical resonator. The cool thing about this optical resonator is it lets any atom talk to any other atom. Photons can travel between these atoms and act like messengers that convey quantum information between them. The light generates correlations, or entanglements.

Once we have prepared atoms and let them interact and entangle, we send in light again to take a picture. So it's literally light just scattering off the atoms. We can see not only where the atoms are, but also which state the atoms are in. The atoms have an internal spin, they can point up or down, and we can look at the spin correlations between different sites of our array of clouds of atoms. So basically, we take a bunch of pictures and analyse the correlations.



Black holes may scramble information that falls inside them

ESA/NASA/JPL-CALTECH/GBT/WSRT/IRAM/C. CLARK (STSCI)

entanglement, a quantum phenomenon in which the properties of particles are correlated such that measuring those of one particle influences the other, even when they are separated by vast distances.

For a long time, such a test seemed beyond us, largely because any measurements you make would collapse the quantum state of your masses, making observations impossible. But in 2017, Sougato Bose at University College London and his colleagues proposed a tabletop experiment that could do the trick.

The idea is to first put a relatively large mass, around a thousandth of a millimetre in diameter, into a quantum superposition. This is where it exists in multiple states at once until it is measured or observed, at which point it is said to "collapse" into a definite state. Then you bring in a second mass, also in a superposition, and let the two masses fall.

If gravity is quantum, you would expect to see gravitons temporarily materialise to entangle the two masses. "If the pairs could get entangled, then gravity must have been quantum in nature," says Bose. "This is how we can verify the quantum nature of gravity." If it is classical, on the other hand, the masses wouldn't be gravitationally superposed and no gravitons would emerge to entangle them.

It is an exceedingly difficult experiment to pull off, not least because quantum states like superposition and entanglement are so delicate. "Even a single atom from the vacuum can collapse the quantum process," says Bose. But we are getting better at avoiding this sort of collapse all the time, as we find new ways to carefully manipulate nanoscopic masses, so Bose is optimistic that his experiment will be possible within in the next five to 10 years.

POST-QUANTUM GRAVITY

If they had to bet on it, most physicists would wager against the true nature of space-time being classical. The other three fundamental forces are quantum, so why not gravity too? "But if you think about it, that doesn't make a lot of sense," says Oppenheim. "We have been unable to quantise gravity, despite more than a century of effort."

Instead, Oppenheim is exploring the

How would quantum gravity emerge from this?

I credit my students, who were very clever in thinking through how you should analyse the data. They realised that one thing you can do is measure the correlations between different pairs of sites in our array of atom clouds and ask which pairs are the most strongly correlated. You can draw a line that connects any of the pairs of clouds that are the most correlated.

What pops out is a tree graph. And thanks to a wonderful collaboration with a theorist, the late Steven Gubser from Princeton, I knew that this tree graph is a representation of curved space-time. The geometry that emerges is something that looks like a space-time with negative curvature. [It is the same kind of space-time involved in the theory of] holographic duality, which doesn't quite look like gravity in our universe, but it's fascinating. This was an important first step for us experimentalists to wrap our heads around precisely what you should measure to see gravity emerge from quantum mechanics.

Does everyone agree your experiment is a simulation of space-time?

First of all, there isn't a consensus about whether holographic duality describes our universe. That is absolutely an open question.

There's a second question of whether these experiments are still a fruitful area of research. Some people are pessimistic, but I have the more optimistic view for two reasons. One is that it may ultimately teach us something deep and fundamental about space-time and gravity in our universe. Secondly, maybe it will help us understand quantum mechanics better, specifically entangled quantum systems.

What other physics are you using your experiment to study?

There are fascinating predictions about what happens to information that falls into a black hole. Not long ago, it seemed like information gets lost when you throw a book into a black hole, which isn't allowed under the laws of quantum mechanics.

The resolution [of this so-called black hole information paradox] is that information isn't completely lost, it's "scrambled". It becomes very difficult to recover because information that was initially locally stored in one quantum bit, or qubit, becomes delocalised and hidden in complex entanglements among many qubits.

There's a theoretical prediction that says if you have the holographic dual of a black hole [the 2D version from which the 3D black hole can arise], it should scramble information extremely quickly. The rate at which that information is scrambled is a fundamental limit for how fast that can happen in any quantum system. This is known as "fast scrambling" and it's neat because [this limit] came from thinking about gravity.

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CHRISTIAN OFFENBERG/ALAMY

Gravitational wave detectors like LIGO can spot tiny space-time fluctuations

possibility that gravity isn't quantum, at least not entirely. His idea is that it is some sort of hybrid, which he calls "post-quantum classical gravity". This means that space-time and gravity can be classical while being consistent with everything else being quantised.

Many people think that you can't combine a quantum and a classical system. But Oppenheim says you can, with a few tweaks to quantum theory and general relativity. For that to work, the interaction between quantum particles and the classical force of gravity must be unpredictable.

So, although it might appear that gravity is quantum in some cases, it may be that any apparent quantum behaviours we see in a gravitational field – a superposition, say – are actually just the result of uncertainty in the position of quantum particles within the field. In which case, measurements of a gravitational field won't give away a particle's position.

Oppenheim has proposed two ways to test this inspired by Henry Cavendish's famous 1797 experiment, which measured the tiny gravitational force between two spheres. Oppenheim's update requires a far greater level of precision, of course. And both of his proposals have the potential to throw up hints that he is onto something with post-quantum classical gravity, or else rule it out to suggest space-time is quantum after all.

The first experiment tests a model by Lajos Diósi and Roger Penrose about the role classical gravity plays on a mass in a quantum superposition. They theorised that for small masses, tiny quantum fluctuations in gravity would be detectable above the gravitational field. But for a big mass, the larger gravitational field would induce the mass's quantum superposition to collapse. On the other hand, quantum gravity predicts that the mass's superposition should persist, not collapse.

The second test is similar, but instead looks for the transition point of a mass switching from quantum to classical behaviour. For example, we know that photons can behave as a particle or a wave, but necklace beads, say, will show only classical behaviour. In other words, they only behave as particles. The question is, at what mass does this transition occur?

Oppenheim has calculated the transition points for a post-quantum classical universe, and is currently in talks with experimentalists. But it isn't easy. "Because gravity is so weak, our measurements of it are very inaccurate," says Oppenheim. "It could be fluctuating wildly and we wouldn't know."

"Gravity could be fluctuating wildly and we wouldn't know"

NON-LOCAL EFFECTS

In 1959, physicists Yakir Aharonov and David Bohm proposed that classical electromagnetic equations don't give the full picture: extra quantum effects must be included. A couple of years later, an experiment verified their prediction by finding that electrically charged particles suffer a "jolt", even in the absence of an electromagnetic field. The most accepted explanation is something known as a non-local quantum effect.

But could this Aharonov-Bohm effect also work for particles in gravitational fields? If gravity is quantum, it should – and it is possible to test that. In January 2022, Chris Overstreet, now at Johns Hopkins University in Maryland, and his collaborators published results, based on this idea, that are perhaps the closest thing we have to proper evidence for quantum gravity.

Their atomic interferometry experiment began with a fountain of ultra-cold atoms that they split along two paths. One path passed by a large mass positioned in such a way that it didn't exert a net gravitational force on the atoms, because its gravity cancelled itself out, leaving quantum gravity as the only possible source of interaction. The atoms on the other path travelled without any external influences.

"We wanted to know if the atoms can still tell whether or not the source mass is present," says Overstreet. They could. And when the two paths were recombined, interference patterns showed that the first path of atoms had shifted compared with the second path. Overstreet says that even after accounting for all possible sources of error, the effect was still significant.

While they aren't yet able to distinguish between post-quantum and quantum gravity, the researchers argue that the quantised version provides a more complete explanation of their demonstration – which paves the way for future experiments.

Overstreet now hopes to further push the experimental envelope at Fermilab, near Chicago, where a 100-metre atom interferometer is currently under construction. This will act as a gigantic quantum sensor, with enough sensitivity to look for gravitational quantisation in – you guessed it – roughly five to 10 years. ▮

Lyndie Chiou is a freelance writer based in California

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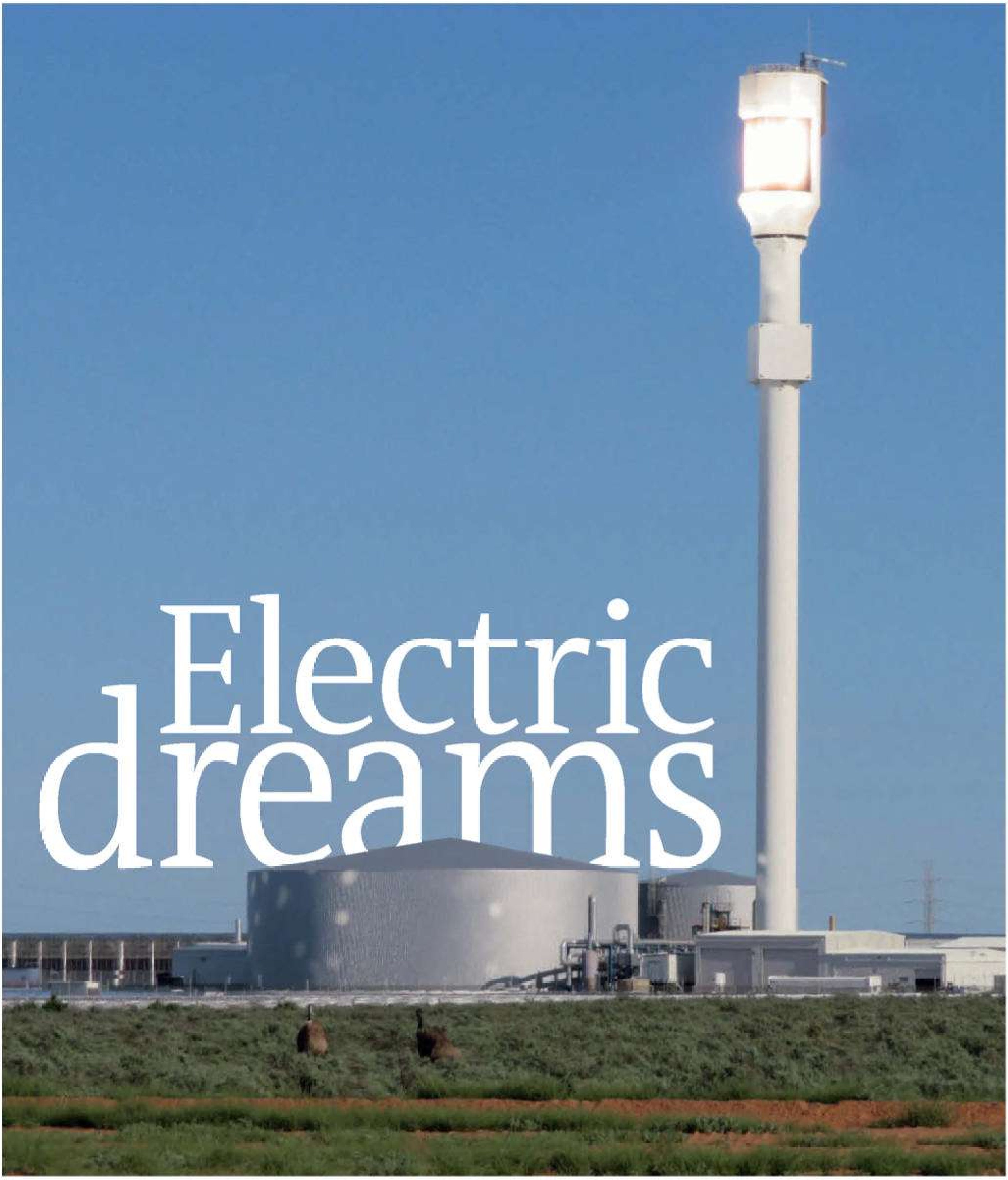
Electric dreams



GARY ROWBOTTOM

South Australia is a solar and wind energy champion and now plans a truly fossil fuel-free grid. How did it make such a remarkable turnaround and can the rest of the world follow suit, wonders **Alice Klein**

A DECADE ago, the main landmark in Port Augusta, a town in South Australia, was a 200-metre-tall chimney puffing fumes from a coal-fired power station. "You could see it from 40-odd kilometres out," says Gary Rowbottom, who worked at the plant for 17 years.

Today, however, there are no hints of this history. The chimney is gone and the sky is a pristine blue. The chief landmark now is a tall tower topped by a dazzling light, where sunlight reflected from 23,000 mirrors on the ground is focused to power four giant greenhouses in which tomatoes are grown. Next door is the newly built renewable energy park, home to 50 wind turbines and 250,000 solar panels.

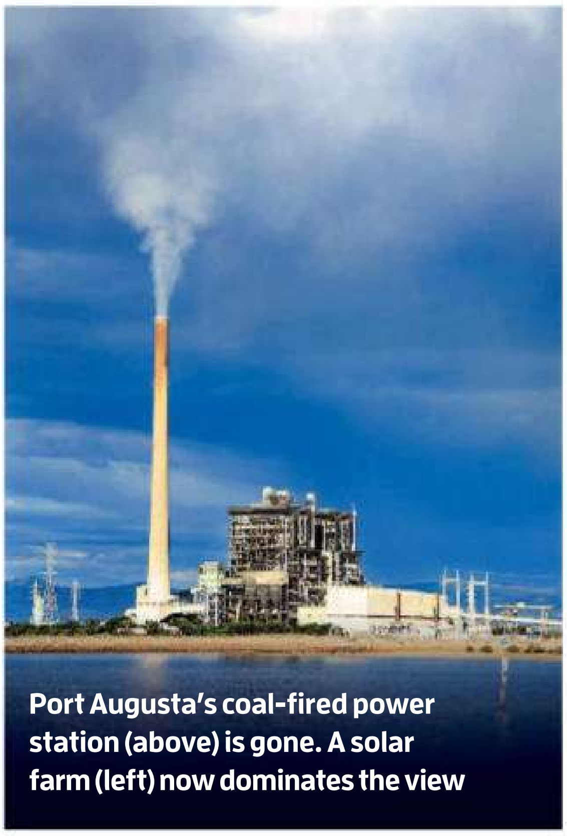
Port Augusta is representative of a remarkable shift that has swept South Australia. In 2007, just 1 per cent of the state's electricity came from solar and wind. Now it is nearly 73 per cent (see graphic overleaf) – the highest proportion of any major grid in the world. On days that are particularly sunny and windy, it powers itself with 100 per cent renewables. That happened on 180 days in 2021 and for a 10-day consecutive stretch in December 2022. The state is now racing to ramp this up to renewable-only power year-round.

Coming from neighbouring New South Wales, where just 31 per cent of electricity is from renewables, I find this clean energy rush highly enviable. It is also highly instructive to the wider world, which needs to rapidly wean itself off fossil fuels to avert a climate disaster. To find out how such progress is possible, I have crossed the border to meet those leading the charge.

South Australia covers almost 1 million square kilometres – more than seven times the area of England – but has a population of just 1.8 million. Almost 90 per cent of the state is desert, so most people live along the wetter, cooler south coast, largely in the capital Adelaide.

The state's renewable energy push began in 2002, when the South Australian Labor Party was elected to government. Its initial interest in renewables was in fact economic, says Tom Koutsantonis, the state's current energy minister under its latest Labor government. At the time, South Australia's electricity was very expensive, partly because its large, spread-out grid is paid for by a relatively small population, and partly because the previous Liberal government had privatised the state's electricity assets "on terms that wouldn't benefit consumers", he says.

The Labor government wanted to "smash up the monopoly" of the newly privatised coal and gas-fired power stations to drive electricity prices down and "the obvious answer was renewables", Koutsantonis tells me at his office in Adelaide. The government realised the desert could actually be a "massive opportunity" because it provided the vast amounts of space, sun and wind needed for competitive renewable energy generation, he says. In 2002, the government approved the state's first wind farm on the Fleurieu peninsula. This opened the floodgates to more renewable energy projects, with 24 onshore wind farms and five large-scale solar farms now operating. In 2008, it also began incentivising households to put solar panels on their roofs by offering generous payments to them for any excess solar energy that was fed back into the grid.



Port Augusta's coal-fired power station (above) is gone. A solar farm (left) now dominates the view

GARY ROWBOTTOM

"We had this at our house and suddenly I was getting credits on my electricity bill because I was selling more than I was using," says Jenny Paradiso, a former librarian in Adelaide who co-founded a solar panel installation business called Suntrix in 2009. As word spread, people rushed to get panels and cash in, she says. Now, more than 40 per cent of South Australian homes have them – one of the highest rates of uptake in the world. One afternoon last month, a major new milestone was reached when the state's entire electricity demand was met by rooftop panels alone.

Certainly, as I drive around, the enthusiasm for solar is evident. There are panels carpeting the roofs of homes, shops, pubs and public toilets. I meet Adam Langham, a chemical engineer in the Adelaide suburb of Netley, who has 58 panels on his house and car port. They produce 12 times more power than he, his wife and two children consume. The government discontinued its subsidy in 2011, but smaller payments are still offered by private electricity companies, meaning the family makes more than enough money to pay off the upfront cost of the installation. "I've had quite a few friends call me up over the years and say, 'OK mate, solar panels, what's the go?' and I tell them, 'they're a no-brainer – go for it'," says Langham.

Wind energy has also been received more warmly in South Australia than in New South Wales, where a planned wind farm near the town of Berrigan was recently scrapped due to a community backlash. One Berrigan resident told the local newspaper the project would "pose physical and mental health threats to our children". Here in South ›

Australia, however, there are framed paintings of wind turbines in my motel room in the town of Burra.

What explains this difference in attitude? Fran Baum, a public health social scientist at the University of Adelaide, says one reason may be that South Australia has a long history of being progressive. It was one of the first places in the world to allow women to vote and stand for parliament, for example, and the first Australian state to decriminalise male homosexuality.

Wind farm developers are also getting better at working with communities, says Tom Jenkins, who heads the South Australian branch of Neoen, a company that is building the state's biggest wind farm, Goyder South. For example, it funds community projects near its wind farm sites, including local clubs and sporting teams; encourages its contractors to employ local businesses; and hires First Nations people to supervise construction in case of the discovery of artefacts or remains. For the Goyder South project, the company will also offer annual payments of AUD$1000 to $5000 to every household within 6 kilometres of a wind turbine as a goodwill gesture.

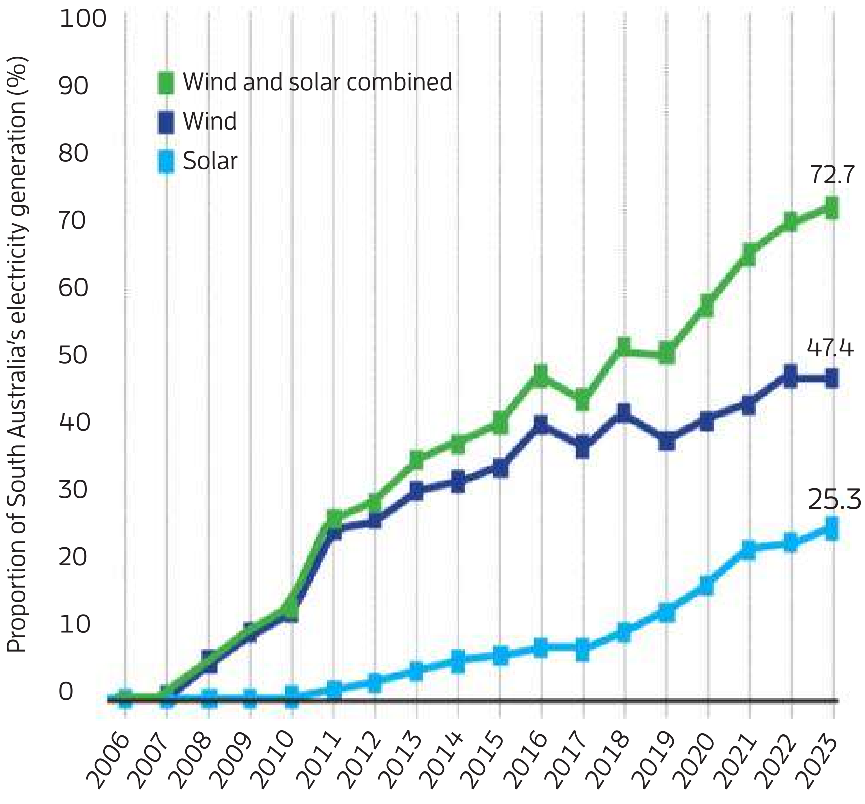
I do, however, meet some people for whom the switch to renewables has been challenging. Rowbottom and around 400 colleagues, for example, lost their jobs in May 2016 when Port Augusta's coal station, the last one in the state, closed. Few were able to find jobs in the town's new renewable energy sector, which required fewer staff and different skills. Rowbottom initially had to move to Queensland to work at another coal power plant, but has since found employment back in Port Augusta.

There have been other hurdles to overcome. In September 2016, South Australia suddenly faced its biggest test yet when almost the entire state experienced a blackout that lasted for days in some areas. "It was the first state-wide blackout like that in Australia in about 50-odd years," says Christiaan Zuur at the Sydney arm of the Clean Energy Council, which represents Australian renewable energy businesses.

The blackout was triggered by a violent storm that knocked over more than 20 electricity pylons and cut three of the four major transmission lines in the state. Coal enthusiasts in the federal government seized on the event to argue that renewables were unreliable. For example, Scott Morrison, Australia's treasurer at the time, who became its prime minister from 2018 to 2022, accused the South Australian government of "switching off jobs, switching off lights and switching off air conditioners and forcing Australian families to boil in the dark as a result of their Dark Ages policies".

Koutsantonis believes the state's supply would have gone down regardless of its energy mix, due to the severe damage to transmission lines. But the mocking that South Australia received made the government there determined to prove the naysayers wrong, he says. "We hated the ridicule we got from the rest of the country."

A giant battery provides backup to the grid in South Australia



SOURCE: OPENNEM.ORG.AU

> "The pressing matter is to find ways to store excess solar and wind energy"

"After the blackout, a whole bunch of very positive things were put into place that have led to South Australia now being where it is – a world leader in terms of its renewables uptake," says Zuur.

In 2017, for example, the state government created a AUD$150 million technology fund to provide grants or loans to businesses that could offer new technologies that would make the grid more resilient.

One project to get funding was a giant battery – the first of its kind in the world – to provide back-up in the event of major grid disturbances. It was built by Tesla following a famous bet on Twitter between Mike Cannon-Brookes, Australia's best-known tech billionaire, and Tesla boss Elon Musk. Musk told Cannon-Brookes that Tesla would get the battery installed and working in less than 100 days, otherwise it would be free. Luckily for Tesla, it achieved this in 63 days.

The battery is near Jamestown and looks like hundreds of refrigerators lined up in rows in a field. Each is filled with lithium-ion cells that are all connected to form one big battery with a capacity of 194 megawatt-hours. The facility monitors the frequency of the local electricity grid and if it suddenly rises or falls, the battery rapidly charges or discharges to stabilise the grid.

BRADLEY COOPER/ALAMY

This has since proved its worth on multiple occasions, including in August 2018, when lightning strikes caused widespread grid problems across the eastern half of Australia. Major blackouts occurred across New South Wales and Victoria, but the lights stayed on in South Australia, as the battery was able to rapidly reverse the sudden drop in grid frequency. Inspired by its effectiveness, Victoria and New South Wales have since built their own big batteries.

The same is true in several US states that are also ramping up their wind and/or solar generation. California, Texas and Florida have recently built or are building big batteries to help maintain the stability of their grids as they change their energy mix.

Another innovative project that emerged after the blackout was a "virtual power plant", also built by Tesla with some initial government funding. It comprises a network of solar panels and batteries that Tesla installed for free on more than 4000 government-owned social housing properties across South Australia. Tesla uses sophisticated software to coordinate the individual systems so they function like a single power plant. This allows it to trade surplus solar energy stored across the battery network on the electricity market.

This appears to be a win-win for everyone because it makes money for Tesla, reduces electricity costs for the social housing residents and helps to stabilise the grid so that blackouts are less likely for the wider community.

I meet Craig Renton, who lives in a social housing property in the outer Adelaide suburb of Elizabeth. He joined the virtual power plant in August last year and says it is "really good". "My wife and I are pensioners and it saves us money – about AUD$60 a quarter – which makes a difference," he says. Renton uses a machine to help him breathe at night and if there was a blackout in the past, "I had to get up to get the generator going, but since we got the battery, now the power comes back on within 5 seconds", he says.

Equitable access

Renton says there is "no way" he would have been able to afford solar panels or a battery without the scheme. In this way, the virtual power plant is helping to address a key criticism levelled at these technologies, which is that they are typically only accessible to the wealthy. "One of the principles that we have in this energy transition is that we want to make sure we don't leave anyone behind," says Scott Oster at the South Australian government's energy department, who has helped manage the project.

Despite all this progress, however, average electricity prices are still higher in South Australia than in most other parts of the country. This has meant there has been "a bit of fatigue creeping in" among the community, with people questioning the benefits, says Koutsantonis. Electricity prices have remained stubbornly high because South Australia still relies on gas-generated electricity to fill the gaps on days when there isn't enough sun and wind, and gas has become increasingly expensive in recent years, he says.

As a result, the most pressing matter now is to find ways to store the excess solar and wind energy produced at particular times of day or on certain days, so it can be used when there is a deficit, instead of falling back on gas, he says. One solution may be to use excess solar and wind energy to power electrolysers that split water to make hydrogen. This hydrogen could then be stored and converted back into electricity when needed, either by burning it or feeding it through hydrogen fuel cells.

To test this idea, the state government will commit AUD$600 million to building a hydrogen power plant near the town of Whyalla, which is due for completion in 2025. If it works, the state will be able to meet its target of running solely on renewables by 2030 and will probably have the world's first large fossil fuel-free grid based on solar and wind energy. "If we can decouple ourselves from coal and gas prices, we decouple ourselves from international price shocks, and then all of a sudden the cost of power is just what it's costing us to generate it," says Koutsantonis.

According to Zuur, there is no reason why other parts of the world couldn't replicate South Australia's rapid adoption of renewables. The state has certain advantages, including large amounts of space, sun and wind, but other places can tap into their own advantages, he says. For example, nations with less land, like the UK and Japan, have built wind farms offshore, while Iceland, which gets little sun, uses alternative renewable resources like hydropower and geothermal energy to generate almost 100 per cent of its electricity.

Personally, seeing what South Australia has achieved in a relatively short space of time has filled me with optimism that the world will be able to wean itself off fossil fuels sooner than we think. Although its energy transition hasn't been perfect, it has shown that the key ingredients for success are strong political leadership, winning community trust, willingness to try new technologies, equitability and, most important, never giving up. ▮

Alice Klein is a *New Scientist* reporter in Sydney, Australia

Ultra-processed, ultra-confusing

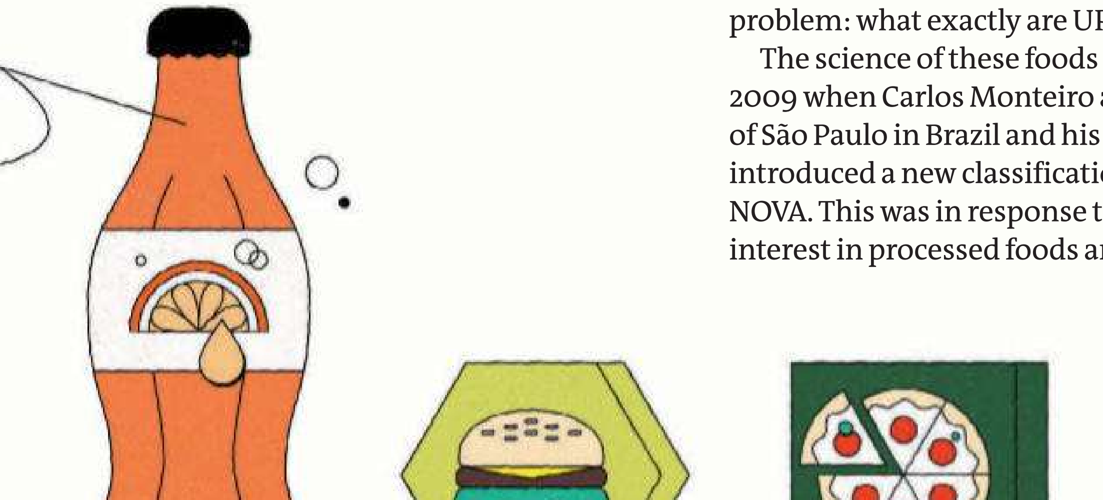
Whether highly processed foods are bad for you, and why, is a contentious topic. **Graham Lawton** attempts to make sense of the conflicting claims

I RECENTLY scoured my kitchen looking for trouble, and I found plenty. There was a packet of instant noodles in a cupboard. Tins of baked beans and a box of muesli. In the fridge, a Jamaican patty, ketchup, hummus and probiotic yoghurts. Over in the bread bin, a loaf. I didn't dare peek in the freezer.

These foods are part of my normal diet, which I don't think is especially unhealthy. But by eating them, I may be opening myself up to obesity, heart disease, a fatty liver, cancer and more. That's if you believe the increasing worries over ultra-processed foods (UPFs) and how bad they supposedly are for our health.

But amid the warnings, there are still many open questions. Are UPFs really bad for you? If so, why? In fact, what exactly are ultra-processed foods anyway? Sprinkle in the myriad social and economic issues intimately associated with the purchase of said foods (see "Ultra-processed do's and don't's", page 42), and it is no wonder everyone is so confused.

In an attempt to get some clarity on the matter, I have spoken to researchers at the forefront of the debate. And while there are no clear answers on UPFs, it is possible to navigate this nutritional quagmire.



NELE ROJEK

Humans have been processing food for millennia to make it tastier, more digestible, more resistant to decay and more convenient. Salting, drying, fermenting, pickling and smoking were invented to preserve foods; milling produced flour to bake bread. Cooking turned unpromising or toxic raw ingredients into tasty, safe and nutritious meals.

During the industrial revolution, however, mechanisation entered the food system. In 1802, the first sugar beet refinery opened in what is now Poland. Ten years later came the first canning factory, in London (sadly not in Canning Town). In 1864, Louis Pasteur invented his eponymous processing technology in which foods are treated with mild heat to eliminate pathogens and extend shelf life. In 1869, margarine was invented. Processed food was on the shelves, and its share of the market has been growing ever since. Around 1950, purchases of processed foods in the West overtook those of whole foods.

The term "ultra-processed food" appeared in the scientific literature in the late 2000s and subsequent studies have linked it to various health conditions. But there was an obvious problem: what exactly are UPFs?

The science of these foods took hold in 2009 when Carlos Monteiro at the University of São Paulo in Brazil and his colleagues introduced a new classification system called NOVA. This was in response to the growing interest in processed foods and the absence of a clear definition of what they were.

NOVA (which is Portuguese for "new") divides foods into four groups: unprocessed and minimally processed; processed culinary ingredients, such as fats, sugars and salt; processed foods, which are created by adding group 2 ingredients to group 1 foods and/or using preservation methods, and, finally, UPFs, making up group 4.

Monteiro defined the last of these as created by the fractioning of whole foods into their constituents, such as sugars, fats and fibres, before these substances are chemically modified and industrially assembled into products, frequently with additives. "It looks a recipe for chronic disease," he says – and increasingly the science suggests he is right.

Processing problem

Foods in this category include breakfast cereals, instant soups, ready-made pizzas and pasta, biscuits, fish fingers, or fish sticks, reconstituted meat products, ice cream, cakes, packaged breads, carbonated drinks and many more. Basically, a lot of what is in my cupboard.

The system broke new and controversial ground in nutrition science by ignoring the nutrients completely and focusing on the degree of processing. The rationale for this, says Monteiro, was because the extent and purpose of processing of foods is now more useful than the nutrient content in assessing their impact on health.

The UPF industry's goal, says Monteiro, is to maximise profits by cajoling consumers to abandon freshly prepared food. "They have affordable prices because of low-cost ingredients, they are convenient, they have long durations, they are engineered to have craving-like palatability and they are aggressively marketed," he says. In the US, Canada and UK, UPFs have long provided around half of all calories consumed, though their rise seems to have plateaued in the past

›

decade. Consumption is still increasing in many other high-income countries as well as middle and low-income ones.

Monteiro says there are easy ways to tell if a product is ultra-processed: it contains at least one food substance rarely used in home cooking – such as high-fructose corn syrup, chemically modified oils or hydrolysed proteins – or additives such as flavourings, colourings, glazing agents or thickeners.

NOVA was quickly adopted by researchers and numerous papers came out on the correlation between category 4 foods and ill health. But the big breakthrough came in 2019, when Kevin Hall at the US National Institutes of Health (NIH) and his colleagues ran a randomised-controlled trial – the gold standard of evidence gathering – to clarify the link between UPFs and obesity.

They recruited 10 men and 10 women with a body mass index of around 27, just slightly over what is deemed "healthy" – and housed them at the NIH Clinical Center in Bethesda, Maryland, for 28 days. For two weeks, the volunteers were fed a diet high in either UPFs or unprocessed food. In the following two weeks, they received the opposite diet. The regimens were equal in terms of overall calorie content, energy density, protein, carbohydrates, fat, fibre, sugars and sodium, but differed widely in the amount of calories from UPFs. The unprocessed diet delivered 88 per cent of its calories via unprocessed foods, mainly whole fruits and vegetables and some meat, fish, eggs and yoghurt. The UPF diet delivered 81 per cent of its calories in UPF form, such as burgers, fries, canned ravioli and hot dogs.

The volunteers were given three meals a day plus unlimited access to diet-appropriate snacks and – crucially – were told they could eat as much or as little as they wanted.

The results were striking. On the UPF diet, volunteers ate around 500 more calories a day than on the unprocessed diet, and after two weeks had gained 0.9 kilograms on average. On the unprocessed diet, they lost 0.9 kilograms, regardless of whether they were given it in the first two weeks or the second. The weight changes were exactly in line with the differences in calorie consumption, says Hall. "There's no magic here, the changes in body weight are directly related to the changes in calorie intake." The conclusion is obvious: UPFs "lead people to overeat calories", he says.

When they dug deeper, the researchers discovered that when people were on the UPF diet, they generally ate bigger meals and consumed more fat and carbohydrates.

Since the work, which remains the only published randomised-controlled trial on UPFs, dozens of other studies have found associations between high UPF consumption and ill health – not just obesity, but also cardiovascular disease, asthma, cancer, depression, inflammatory bowel disease, fatty liver disease, kidney disease, type 2 diabetes and all-cause mortality. For the latter, one study found that the highest consumers of UPFs were 1.62 times more likely to die during the study, which followed almost 20,000 people between 1999 and 2014, than the lowest consumers.

NASTYAOFLY/SHUTTERSTOCK

According to Monteiro, more than 70 high-quality studies have now been published showing a relationship between consumption of UPFs and 20 illnesses.

That may sound like clinching evidence, but there is plenty of wiggle room. Except for Hall's randomised-controlled trial, all the data comes from observational studies, where subjects are monitored in their normal life. These produce a lower standard of evidence than a randomised-controlled trial and aren't considered definitive proof of cause and effect – confounding factors can bias the results.

This uncertainty has led some critics to downplay the link between UPFs and ill health. One recent review concluded that "to date, there is insufficient documentation of a causal role played [in obesity] by processing" and criticised Hall's randomised-controlled trial as "limited", in part because the 20 subjects didn't find the UPF diet more palatable than the unprocessed one. The lead author of the review disclosed that he is a member of the scientific advisory boards of Mars Foods and the Grain Foods Foundation, although no funding was received for the study.

Monteiro dismisses these critics. But he accepts that the causal mechanisms remain unclear, beyond the obvious one of UPFs delivering poorer nutrition via high calorie and salt loads and reduced fibre, vitamins, plant chemicals and micronutrients. "I suspect there's more than one mechanism linking UPFs with different diseases," he says.

Last year, a team led by Bernard Srour at the University of Paris, France, proposed several mechanisms that could contribute to the unhealthiness of a high-UPF diet. One is that

ULTRA-PROCESSED DO'S AND DON'T'S

DO cut down
Keep your calories from ultra-processed foods under 20 to 30 per cent of your total calorie consumption. This is the point at which studies see a link between UPFs and ill health (see main story).

DO diversify
Alongside any UPFs, eat 30 whole foods, such as pulses, grains and vegetables, per week. This is linked to reduced inflammation associated with better physical and mental health.

DO be discerning
Not all ultra-processed foods are as unhealthy as each other. Seeded, wholegrain bread from a supermarket may be fortified with essential nutrients and be nutritionally more beneficial than a home-made white loaf.

DON'T panic
Studies linking additives such as acrylamide or emulsifiers to cancer and other conditions haven't been substantiated in human trials.

DON'T judge
Ultra-processed foods are safe, convenient and cheap, and can often supply much-needed nutrition to families. Replacing UPFs with home-cooked meals where you can is a more sustainable and healthy change for most people.

People eat more calories on an ultra-processed diet

> **"Not all ultra-processed foods are equally unhealthy"**

extreme processing makes the foods softer and easier to consume, digest and absorb, and hence promotes overeating. Indeed, Hall found in the randomised-controlled trial that when people were on the UPF diet, they ate faster, at a rate of 50 calories per minute versus 30 on the unprocessed diet.

This is perhaps the most pressing question surrounding UPFs: is the processing itself partly responsible for their health effects? Monteiro thinks so and some others agree. In April, doctor and academic Chris van Tulleken, who is author of *Ultra-Processed People: Why do we all eat stuff that isn't food… and why can't we stop?*, told *New Scientist*: "When you separate [whole foods] into their molecular components and chemically modify them, they seem to interact with the body in a very different way."

But others aren't swallowing it. "We think it's unclear, due to limitations in the available evidence, whether the associations are due to the nutritional characteristics of the food or whether there's any independent effect of the processing," says Ian Young at Queen's University Belfast, UK, speaking in his capacity as chair of the UK's Scientific Advisory Committee on Nutrition. "We believe it's mostly due to the nutritive and sensory properties of those foods, not a specific characteristic of their degree of processing," says Ciarán Forde at Wageningen University in the Netherlands, who was involved in Hall's randomised-controlled trial and is working with him on another to probe further.

Another of Srour's proposed mechanisms is that UPFs could be contaminated with toxins leached from packaging or created during processing and heating, such as acrolein, acrylamide, trans fats and advanced glycation end products. These are currently a major focus of dietary epidemiology, according to Edith Feskens, also at Wageningen University.

Disruptive additions

Additives could be a culprit, too: there are more than 300 in use in the European Union and most aren't under suspicion, but there is some evidence linking emulsifiers – which enable oily and watery liquids to mix – to inflammatory bowel disease and cardiovascular disease. But Feskens is sceptical. "It's difficult to imagine how a small amount of emulsifier can have such an impact," she says.

UPFs may also disrupt the microbiome. Human guts contain trillions of microbes that play a crucial role in digestion, metabolism and immunity. Studies in mice and humans have shown that compounds present in UPFs can alter the microbiome in ways that promote inflammation.

One stinging criticism of the whole debate over UPFs is that this is just old science with a new label – that NOVA is simply a new way to categorise foods that are high in salt, sugar, fat and refined carbohydrates, which are already known to be unhealthy in large quantities. "Is this really anything new?" asks Hall.

Another criticism of NOVA category 4 is that it captures foods that are actually pretty healthy. A supermarket wholemeal loaf is classed as ultra-processed because it contains additives, according to Feskens. An equivalent loaf from an artisan baker would feature in category 3 despite being nutritionally almost indistinguishable, she says. In fact, it may be nutritionally inferior because supermarket bread is often fortified with nutrients. Around 55 per cent of Dutch fibre consumption comes from UPFs, largely bread, she says, so in that respect the NOVA category 4 is unhelpful. "Not all UPFs are equally unhealthy," says Feskens.

According to Srour, of more than 220,000 group 4 products available in France, 21 per cent had a good nutritional score according to the country's guidelines. Some researchers, including Feskens, think that NOVA's category 4 could be split in two to differentiate between "good" and "bad" UPFs.

NOVA is also subjective, with experts sometimes disagreeing wildly on the category foods should be in. A recent study asked more than 300 nutrition professionals to categorise 231 different foods; there was unanimous agreement on only four. This calls into question NOVA's usefulness as a tool to make dietary recommendations or policy, says Forde.

Nonetheless, Monteiro stands by his classification and says there is now enough evidence to take public health action. His strategy is based on efforts in tobacco control: provide reliable information in dietary guidelines, restrict or prohibit advertising, put warnings on packaging, ban sales in schools and tax the products heavily while subsidising unprocessed and minimally-processed foods. Indeed, his native Brazil has been advising people to avoid UPFs since 2014.

That, however, may be counterproductive. Demonising category 4 foods or restricting access to them will deprive a lot of people of nutritious, cheap and convenient foods. It may also make the industry less inclined to develop better processing techniques to enhance the nutritional quality of foods, says Pete Wilde at the Quadram Institute in Norwich, UK. "There is a real risk of demonising foods that are otherwise nutritionally adequate or even beneficial," says Forde.

So where does that leave us? "Most people would benefit from a reduction in their intake of UPFs, purely based on their nutritional content," says Young. But how much is too much? "That's a big question," says Monteiro. "We've been looking for this threshold. The data says that the mechanisms are dose dependent. Five to 10 per cent of calories [from UPFs] won't have a big effect on health, but at 20 to 30, the problems start to appear."

Ultimately, for most consumers with busy lives and finite food budgets, UPFs are hard to avoid altogether and rather handy to have. My store cupboards tell a story: I try to cook from scratch, but often don't or can't. I confronted the freezer and found a ready-made pizza. I will definitely eat it. With a salad. ■

Graham Lawton is a features writer at *New Scientist*

The back pages

Puzzles
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***Almost* the last word**
Why does a fallen tree grow vertical stems from its trunk? p46

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Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

Mathematics of life

Homing in on an answer

Rob Eastaway and **Brian Hobbs** take over our maths column to reveal that spiral search patterns were key to cracking their puzzle

Rob Eastaway (left) is a maths author; Brian Hobbs is a puzzle podcaster. Together, they compiled the *New Scientist* puzzle book *Headscratchers*.

WHEN solving problems in the real world, it is rare that the solution is purely mathematical, but maths is often a key ingredient. The puzzle we set a few weeks ago (*New Scientist*, 30 September, p 45) embraced this by encouraging readers to come up with ingenious solutions that didn't have to be exclusively maths-based.

Here is a reminder of the problem: Prince Golightly found himself tied to a chair near the centre of a square room, in the dark, with chained monsters in the four corners and an escape door in the middle of one wall. With him, he had a broom, a dictionary, some duct tape, a kitchen clock and a bucket of water with a russet fish.

John Offord was one of several readers to spot an ambiguity in our wording. Four monsters in each corner? Did this mean 16 monsters? John suggested the dictionary might help the captors brush up on their grammar.

The russet fish was deliberately inserted as a red herring (geddit?), but we loved that some readers found ways to incorporate it, either as a way of distracting the monsters or as a source of valuable protein for a hungry prince. Dave Wilson contrived a delightful monster detector, while Glenn Reid composed a limerick with the solution of turning off the computer game and going to bed.

And so to more practical solutions. Arlo Harding and Ed Schulz both suggested ways of creating a torch by igniting assorted materials with an electric spark from the light cable. But Ben Haller and Chris Armstrong had the cleverest mathematical approach. After locating the light fitting in the room's centre with the broom, they used duct tape and rope to circle the centre, increasing the radius until they touched the wall at what must be its centre, and then continued circling to each wall till they found the escape door. Meanwhile, the duo of Denise and Emory (aged 11) used Pythagoras's theorem to confirm the monsters in the corners would be safely beyond reach. They, plus Ben and Chris, win a copy of our *New Scientist* puzzle book *Headscratchers*.

STEVE WOODS PHOTOGRAPHY/CULTURA CREATIVE RF/ALAMY

It is unlikely you will ever have to escape monsters in this way, but spiral search patterns when visibility is limited are employed in various real-world scenarios: rescuers probing for survivors in avalanches, divers performing underwater searches and detectives examining crime scenes, for example. Some telescopes have automated spiral search algorithms that help locate celestial objects. These patterns allow for thorough searches while ensuring you don't stray too far from your starting point.

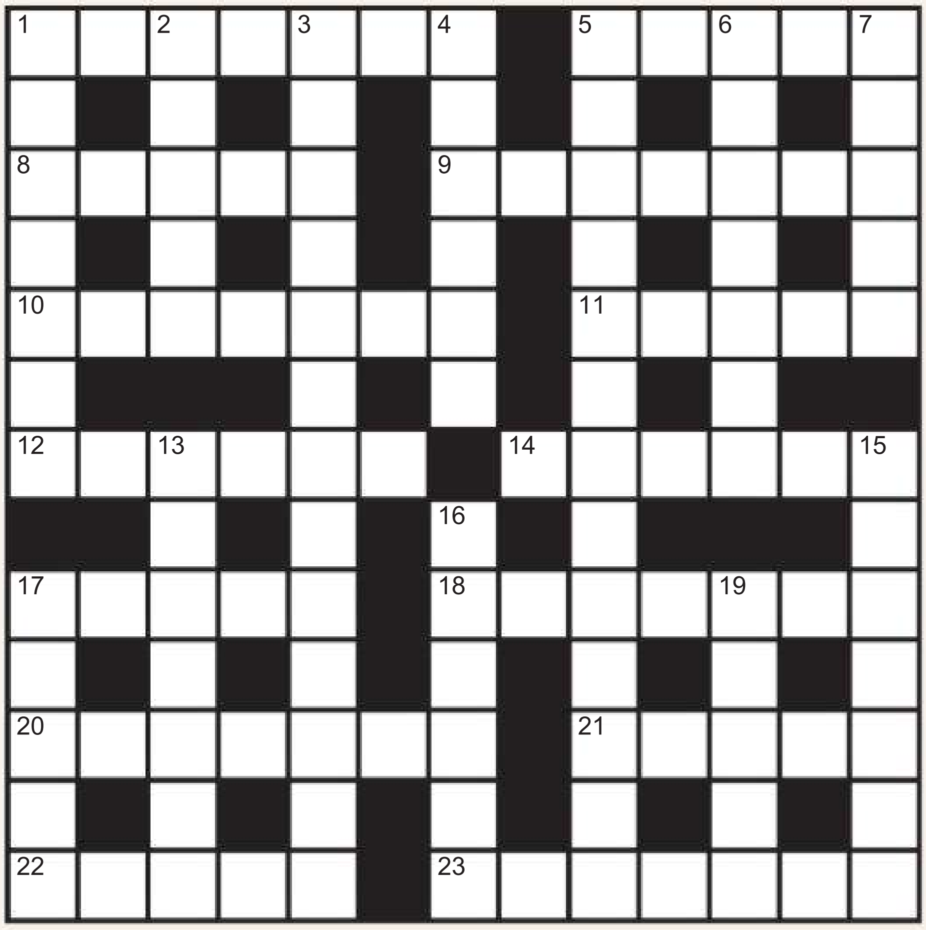
Of course, like all real-world problems, mathematical nous isn't enough. As our readers have displayed, lateral thinking and the ability to improvise are human skills that help us find the creative solutions an algorithm would miss. ▮

These articles are posted each week at newscientist.com/maker

Mathematics of life reveals the mathematical ideas and shortcuts behind everyday situations

Next week
Debunking gardening myths

Cryptic crossword #121 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Hollow stem contains silver-white allergen (7)
5 Lighter mass at constant height (5)
8 Lit up cracked bulb (5)
9 Large snakes climbing structures (7)
10 Sue's limitless lapidary style (4,3)
11 Lab test stripped vase, for instance (5)
12 Use electromagnetic ring in layer (6)
14 Reportedly choose appropriate summer outing (6)
17 Fixed Atari headgear (5)
18 Return seized vehicle and programmer's object (7)
20 Re: Extremely rich source of uranium in western mine (7)
21 Charge after a lagoon's protector (5)
22 Bananas grown in error (5)
23 Yell, point, and identify Nessie, maybe (7)

DOWN

1 Resistance over electrical engineer taking in weary pensioner (7)
2 Winds finally overturning beers (5)
3 Hawking giving a speech in support of trust (13)
4 Princess with stringed instrument lacking concentration? (6)
5 Contemporary school subject involved dicey material (5,8)
6 Eighties sci-fi film conveys effortless, endless crime (7)
7 Rough-sounding canine (5)
13 Control bad smell beneath venue (7)
15 Gently cooked fish before daughter took charge (7)
16 Immense company's karaoke accessory (6)
17 Auditioner's completed cast (5)
19 Assume inclined shelters suffice (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #225

set by Bethan Ackerley

1 Who first proposed the three-body problem?

2 Denisova cave, a site containing remains of ancient Denisovan hominins, is in which country?

3 What is the atomic number of gold?

4 Extant mammals that lay eggs rather than bearing live young, such as platypuses, are known as what?

5 The hormone leptin is primarily made by which kind of cell?

Answers on page 47

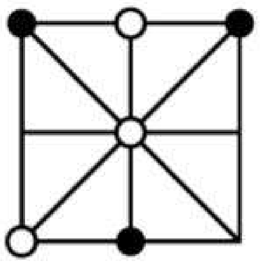
Headscratcher

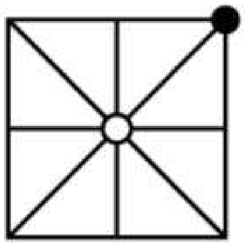
set by Rob Eastaway

#245 Three men's morris

The game of three men's morris was invented hundreds of years ago. It was eventually superseded by noughts and crosses, or tic-tac-toe.

To play, you draw a grid. Each player has three counters, and the aim is to get three of your colour in a row, column or diagonal. The players take it in turn to place a piece on a junction. If there isn't a winner after all the pieces have been placed, you can slide one of your pieces to an adjacent empty junction on your next move. So, in the game shown on the left below, white could move the bottom-left piece up or the piece in the centre in one of three directions.





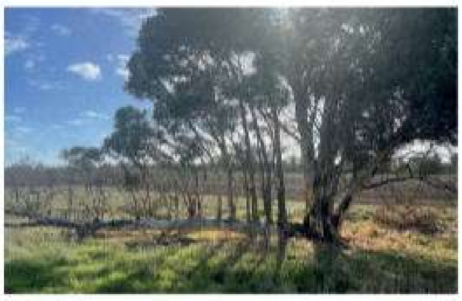
Alpha and Zoe are playing a game, shown above right. Alpha is first and puts her piece in the centre. Zoe goes for a corner. Alpha smiles. She thinks she can guarantee a win in... how many more moves? And should Zoe have gone for middle top instead?

Solution next week

Gum up

Why and how do fallen trees, such as this white gum from Western Australia (pictured below), grow stems vertically from a horizontal trunk?

Pat French
Telford, Shropshire, UK
Two major factors that contribute to the specific shape of a tree are its genetics and the flow of auxins, their growth hormones.


ANNA BUTCHER

A tree inherits the density, position and angle of its buds from the DNA of its species. In early years, branches may be staggered or paired depending on bud position and orientated by their angle to give a typical tree shape.

> **"The stump of a recently felled iconic sycamore tree by Hadrian's Wall in the UK could be left to regenerate and form a coppice"**

However, there is also the auxin effect. These hormones are controlled by external factors.

The auxins in tree roots tend to be "positively geotropic": they accumulate in such a way that a root grows towards a gravitational pull, in other words, downwards.

In the branches, the hormones are negatively geotropic and positively phototropic, causing growth away from gravity and towards light.

An unshaded stem such as the central one tends to grow straight up even when the sunlight in its location always falls at an angle (that is, beyond the tropics of Capricorn and Cancer). This is because growth in opposition to gravity predominates. For shaded lower branches, growth towards light predominates and they tend to grow outwards towards it. These factors combine to give the tree its recognisable shape.

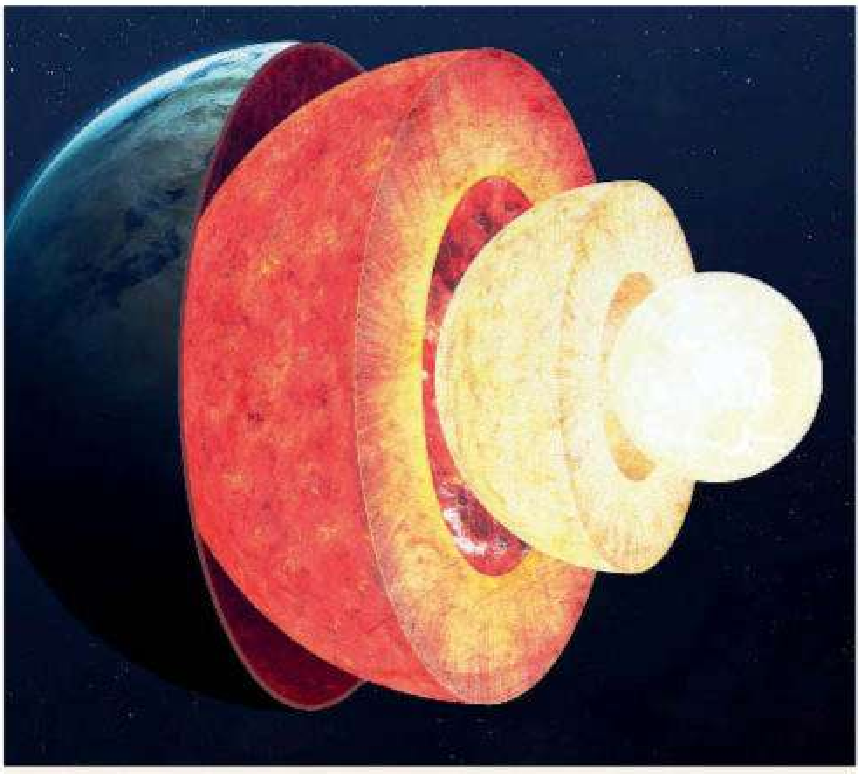
When the gum in question fell, a number of dormant buds along the trunk were exposed to clear sunlight and therefore started to grow vertically upwards, as seen in the picture. As competition develops and subsequent sub-branches become shaded, each treelet will form the typical white gum shape. Eventually, the whole group of new trees will combine. Some stems will be so shaded that they die out and the whole group will take on a shape still recognisable as a white gum.

Recently, an iconic sycamore tree, growing by Hadrian's Wall on the border between England and Scotland, was felled. One option is to let the stump regenerate by growing many new stems, forming a coppice that will eventually adopt the shape of a wide sycamore tree.

Chris Daniel
Glan Conwy, UK
Plants respond to external stimuli such as light, moisture and gravity. The new vertical growth from the tree in the picture shows the tendency of plant stems to grow in the opposite direction to the acceleration due to gravity, a property that is known as negative geotropism, or negative gravitropism.

Gravity-sensing cells called statocytes in the plant shoots contain starch-producing organelles called statoliths, which are denser than the surrounding cytoplasm in the cell and sink to the bottom under the influence of gravity. This chemically triggers an asymmetric distribution of auxin, a hormone that regulates plant growth. This can, for example, cause increased growth and lengthening of the cells on the lower side of a shoot, so that it curves upwards against gravity and towards the light. Strangely, in roots, auxin has the opposite effect, called positive geotropism or positive gravitropism, causing the roots to grow downwards.

Horticulturalists and farmers make use of negative gravitropism in plants. The branches of fruit trees can be trained horizontally in espaliers to improve fruit production. The low auxin content on the upper side of the branch allows shoots called watersprouts to grow, orienting themselves vertically against gravity. In traditional hedge-laying, the main stems of shrubs are trimmed and partially cut through near the ground, then bent over at 35 degrees or more and tied into position. This stimulates new growth from the stems, generally in the vertical direction, to create a dense, living fence that provides a refuge for wildlife and containment for livestock.


VADIM SADOVSKI/SHUTTERSTOCK

Why does our planet have a core of iron and not some other abundant element?

This week's new questions

Middle-earth **Why does our planet have an iron core, rather than one made of another abundant element such as silicon?** ***Greg Tanner***, *Melbourne, Australia*

Suck it up **Why does a slightly damp sponge absorb water so much better than the same sponge when it is bone dry?** ***Bert Laan***, *Ashurst, Hampshire, UK*

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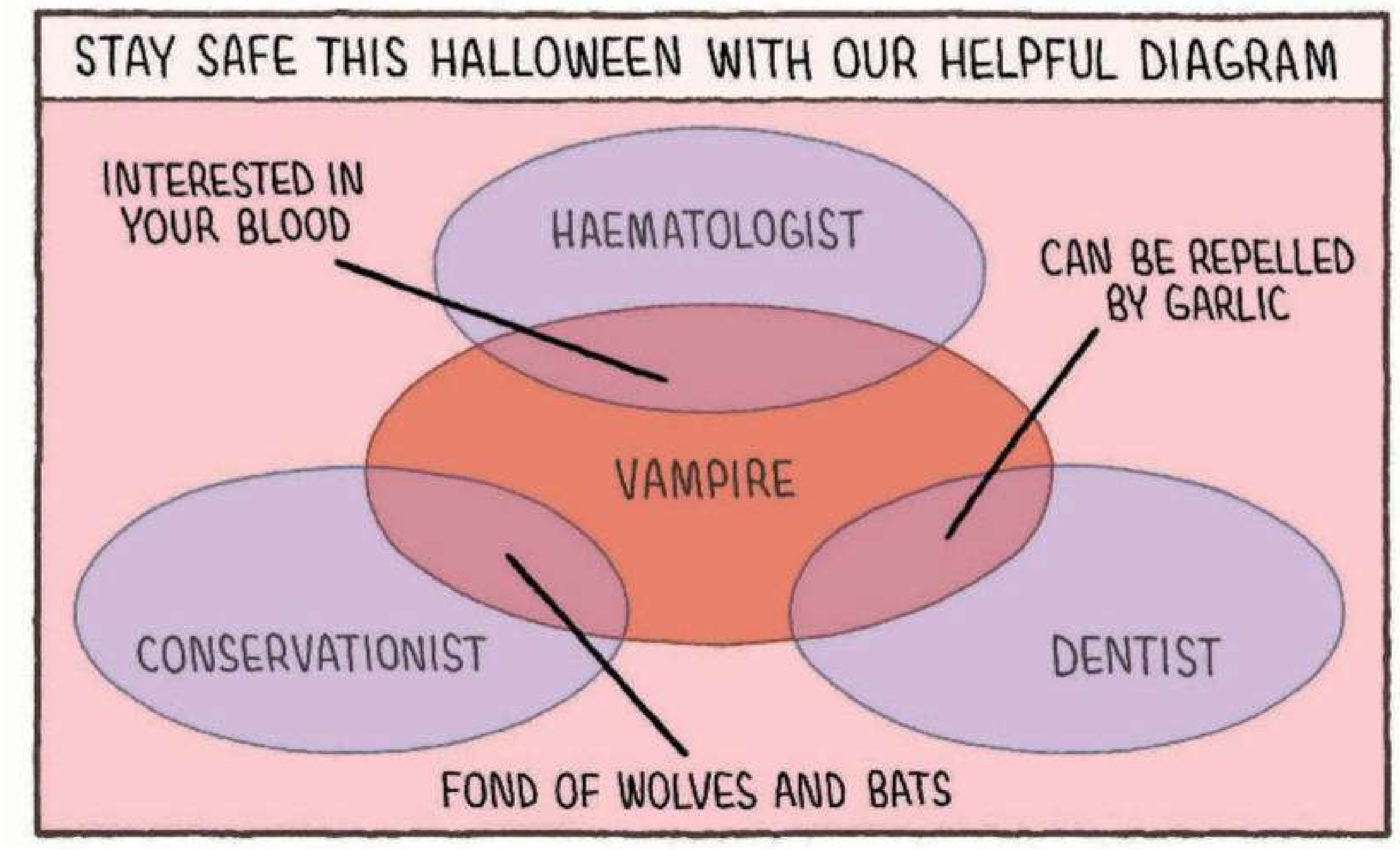
Spinning out

What makes galaxies spin in a certain direction? And do they all spin in the same direction?

Mark Thompson
Tewkesbury, Gloucestershire, UK
No, they don't all spin in the same direction. Galaxy rotation is complex and diverse. These objects come in various shapes and sizes, and their rotational patterns can differ significantly.

There are a few main types of galaxies. Spiral ones, like our Milky Way, have a central bulge

Tom Gauld
for New Scientist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surrounded by spiral arms. These galaxies often exhibit a coherent rotation, where the stars and gas in the disc generally move in the same direction around the galactic centre. However, the direction of rotation can vary from one spiral galaxy to another.

Elliptical galaxies are generally more spheroidal or ellipsoidal in shape and lack the prominent spiral arms of spiral galaxies. They don't have a well-defined rotational disc, and the motion of stars within them is more random. As a result, the concept of "spin direction" is less applicable to elliptical galaxies.

Irregular galaxies don't have a regular, symmetric structure like spiral or elliptical galaxies. Their shapes and rotational patterns can be highly chaotic, with stars and gas moving in various directions.

Furthermore, when two galaxies collide, their gravitational forces can disrupt their original rotational patterns, leading to more complex motions.

In summary, while some galaxies may exhibit coherent rotation in a particular direction, there is no universal rule that dictates all galaxies spin in the same direction in this way.

> **"Some galaxies flip over and present to us their nether faces, a gesture which is known to astronomers as 'mooning'"**

David Bortin
Whittier, California, US
Most galaxies didn't form during the era of analogue clocks; those that did are too recent for their light to have travelled to us.

Consequently, no galaxy can tell clockwise from counterclockwise. Still, they instinctively sense that they are bound to comply with the law of conservation of angular momentum. Some of them, frustrated by this indeterminacy, flip over and present to us their nether faces (a gesture known to astronomers as "mooning"), from which perspective their spin appears to us to be reversed.

All in the mind

Why can't we conjure up smell and touch in our heads, but we can "listen" to music when nothing is coming through our ears? (cont.)

Martin Freeman
London, UK
My work used to enable me to travel in a small company aircraft. Flying south in the UK from Glasgow to London, we were once a little late and the airfield landing lights were turned on. The pilot knew I had previously flown in the Royal Air Force (RAF) and asked if I wanted to join him in the second seat at the front. Delighted, I settled in to memories of flying Canberras [large, jet-engined aircraft]. Suddenly, I experienced a spontaneous, unmistakable smell and taste in my mouth of egg, chips and beans in a fry-up. Bewildered, I then realised it was a vivid physical memory of RAF night-flying suppers – always available and popular both before a late-night take-off and after an early morning landing. ▮

Answers

Quick quiz #225
Answers

1 Isaac Newton
2 Russia
3 79
4 Monotremes
5 Adipose cells

Quick crossword #144 *Answers*

ACROSS 1 Astronomer Royal, **9** Glutei, **10** Gridiron, **11** Pasadena, **14** Wigner, **17** Nitroglycerin, **20** Recumbent bike, **23** Indium, **25** Axletree, **28** Ebb tides, **29** Myxoma, **30** Tensile strength

DOWN 2 Sylvan, **3** Retia, **4** Noise, **5** Magma, **6** Railway, **7** O ring, **8** Long-range, **12** Datum, **13** Noose, **15** Nerve, **16** Corrigent, **17** Nicad, **18** Latex, **19** Cline, **21** Bimodal, **22** Fermat, **24** Iotas, **25** Apsis, **26** Lemur, **27** Toxin

#244 Wheel-to-reel
Solution

The coach was going at 8 yards per second. The back wheels are 4 yards in circumference with 24 spokes, and the front wheels are 3 yd in circumference with 12 spokes (3/4 the diameter means 3/4 the circumference as well). As the back wheels rotate, they will appear the same every 1/6 yd (4 yd/24 spokes). The front ones appear identical every 1/4 yd (3 yd/12 spokes). The shortest distance that both sets of wheels will appear the same together is every 1/2 yd. So, if every frame represents 1/2 yd of travel, then the wheels would appear not to move. At 16 frames a second, this translates to 8 yd/s of stagecoach speed, just over 16 miles per hour. In theory, it could have also gone 1 yard per frame, but this would be 32 mph, faster than Usain Bolt.

Life's a game

Here is good news for gamers, from Catarina Matias at Lusófona University in Portugal and her colleagues.

The team studied 235 Portuguese gamers, explaining (in the journal *Computers in Human Behavior*) that the bulk of them don't conform to the unhappy stereotype of gamers having "mental disorders and an unhealthy lifestyle pattern".

Detractors say gamers are oddballs. But the study says that half of the gamers report having "good psychological well-being", and that only three were diagnosed as having internet gaming disorder. And, snorts the study, the official definition of the condition is itself "highly controversial".

Detractors say gamers mainline junk food. But most of the participants "reported not consuming snacks while gaming". (The researchers do point out that "some of the information could have been not correctly collected, such as nutritional information during the day or snacking habits for gamers".)

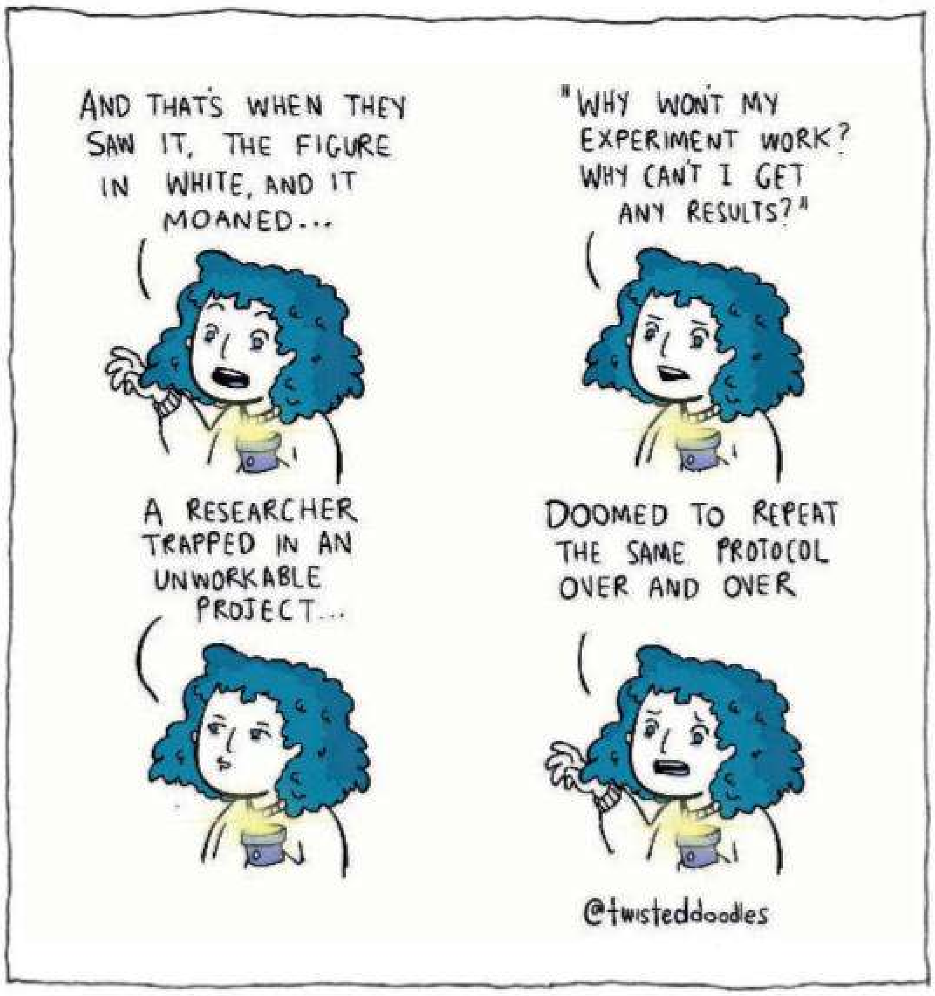
Detractors say gamers eschew sleep. In this, the study agrees, saying: "Poor sleep quality was observed in this population." In a press release, the researchers go further, making a technically correct blanket statement: "even playing video games for a short duration may negatively impact their sleep and mental health".

Feedback is inspired to respond. Citizens, awake! Gaming doesn't stand alone. The public has seen Mayday!-ish warnings about many other, unrelated activities that "may negatively impact sleep and mental health". One might conclude that every kind of activity may do so.

Is life entirely a game of hazards? Does every activity bring danger? Let's find out.

If you know of an activity that has been reliably proven to NOT negatively impact sleep and mental health, please send documentation to "No Negative Impact", c/o Feedback.

Twisteddoodles *for New Scientist*


AND THAT'S WHEN THEY SAW IT, THE FIGURE IN WHITE, AND IT MOANED...
"WHY WON'T MY EXPERIMENT WORK? WHY CAN'T I GET ANY RESULTS?"
A RESEARCHER TRAPPED IN AN UNWORKABLE PROJECT...
DOOMED TO REPEAT THE SAME PROTOCOL OVER AND OVER
@twisteddoodles

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Consideration of items sent in the post will be delayed

Glaring proof

Research done at Texas Tech University prods a person to reflect on a fact: the software in our everyday life grows ever more complex by creating and tackling ever more complex problems, the solutions to which create still more complex problems.

Hassan Wasswa and Abdul Serwadda conducted a study called "The proof is in the glare: On the privacy risk posed by eyeglasses in video calls". They show (they say) that "even when equipped with anti-glare functionality, eyeglasses worn during a video call could leak information that the user privately views in their computer window".

To solve this problem, they call for "the incorporation of filters designed to specifically obfuscate content in eyeglass reflections".

They warn that people should be "cautious about the information they display on their computer screens while wearing eyeglasses during video calls". Feedback adds a bonus warning: Look ahead and watch out for intriguing problems that might arise from the installation of those eyeglass-reflection-content obfuscation filters.

And the problems that might arise from attempts to overcome those new problems.

O! E! What?

Non-scientists aren't alone in their confusion at reading scientific papers. Scientists who glance at papers about specialities other than their own stumble on phrases that baffle them too.

Anyone can feel ignorant and embarrassed. Do you know what "O horizon" means? Do you? If a stranger, in conversation, were to say "E horizon", would you internally cower in confusion and shame? Would you?

If you are a scientist who studies tundras, invasive earthworms or soil structure, perhaps you pepper and salt your everyday conversation with those two phrases. Otherwise, Feedback leaves you to your own devices (an internet search, a paper dictionary or a clever 10-year old) to discover what the phrases mean.

If you aren't a scientist who studies tundras, invasive earthworms or soil structure, perhaps you crave the unsettling thrill of wondering at the meaning of "O horizon and "E horizon". If so, get yourself a copy of the study "Holes in the tundra: Invasive earthworms alter soil structure and moisture in tundra soils", in the journal *Science of the Total Environment*. It includes many mentions of the former phrase, two mentions of the latter and no definition of either.

Many researchers write studies with tightly focused wording. Some take pride in doing so. Others do it under duress – heeding the desires or warnings of their supervisors, peers or publishers. To potential readers outside the focused field, those papers offer new horizons.

Under footage

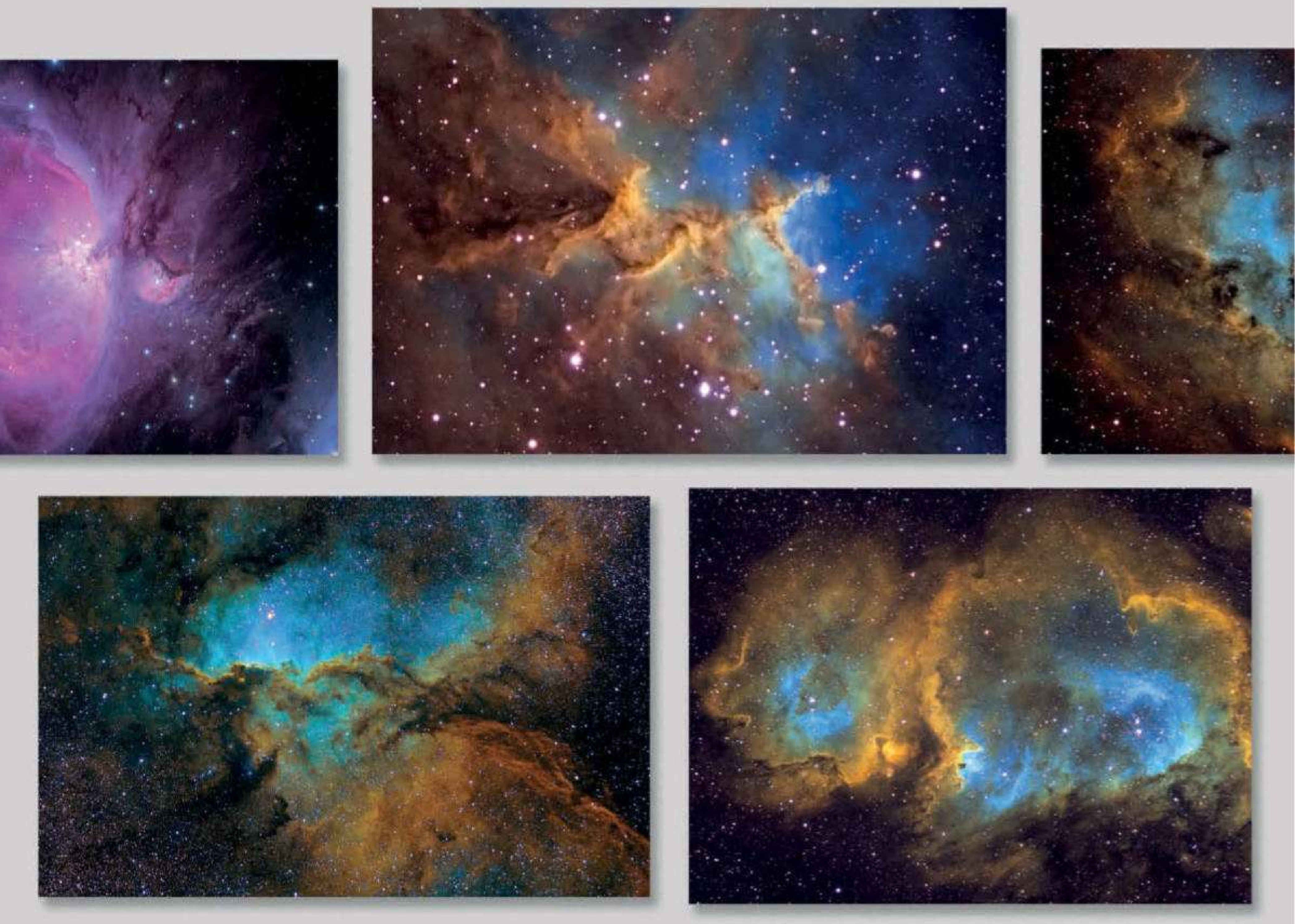
The green-and-white sign you see here is plastered on the floor of the Dana-Farber Cancer Institute in Boston, Massachusetts. It says: "MAINTAIN 6 FEET THANK YOU".

Upon inquiry, Feedback was told that no, the sign is not a plea to protect and defend our planet's insects. ▮

Marc Abrahams

GALAXY
ON GLASS

SPECTACULAR WALL ART FROM
ASTROPHOTOGRAPHER CHRIS BAKER



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